APPENDIX D

SITE SPECIFIC PROCESS DETAIL

1.0 FERNALD

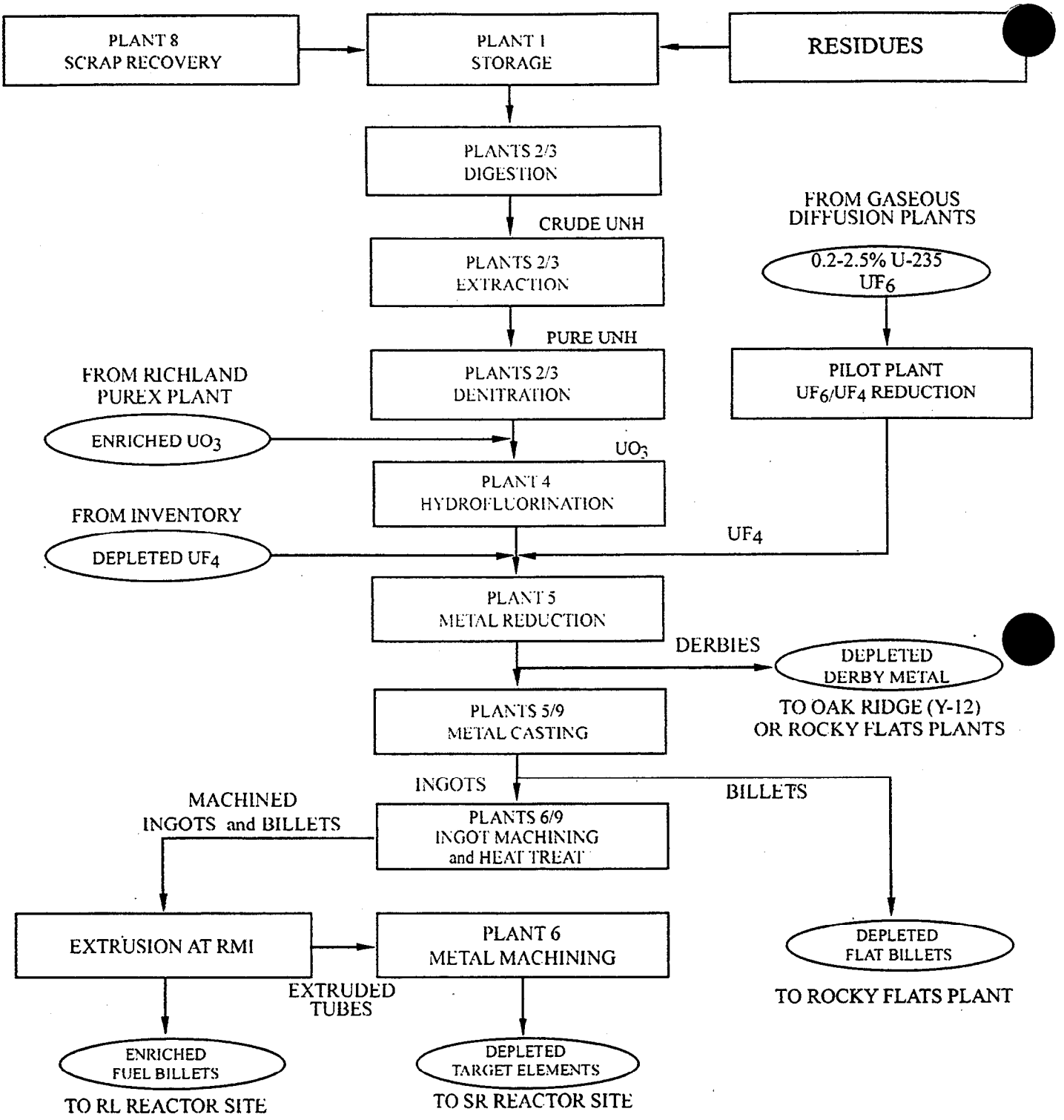
The historical production processes at the FEMP consisted of ten production plants, each having a specific mission that supplied the succeeding plant with an intermediate product for further processing until the eventual uranium form was produced. A schematic diagram of the overall production process is shown in Figure D-1, and a detailed description of each plant process, production activity, and significant events is presented in Attachment 1 to this Appendix. Deliveries of depleted, normal, and enriched uranium metal products for the 32-year period, from startup through 1985, are presented in Table D-1.

Operations began in October 1951, with the completion of the Pilot Plant as an operating prototype of the entire production process to develop performance data for designing large-scale equipment. At the same time, limited quantities of uranium metal were produced. In December 1953, the Sampling Plant (1) became operational and eventually was designated the official AEC sampling station for determining uranium and isotopic assays of uranium ores and concentrates. The three metal production and fabrication plants (5, 6, and 9) became operational by 1953 and all five chemical plants (2, 3, 4, 7, and 8) one year later. Subsequent to start-up, Plants 2 and 3 were consolidated into a single plant because of the integral process operations and usage of workforce.

Extensive technical support was provided to the plants as operations moved through initial start-up to full-scale operation of the primary process streams. The Analytical Department personnel developed numerous methods of quantitative analyses, involving new techniques and applications of equipment. Hundreds of analytical methods were established for supporting the primary processes, ongoing technical development work and attendant changes. Numerous spot tests were devised for chemical operators to perform process quality control checks for ensuring conformance with manufacturing standards. A high performance standard was maintained in all operations through continual improvements of manufacturing methods, technology innovations, emphasis on safety and good housekeeping practices, and upgrades to work facilities.

1.1 CHEMICAL PROCESS OPERATIONS

The FEMP production process began with the conversion of impure uranium feed materials and recycled residues to pure uranium trioxide (UO_3) in the Ore Refinery Plant (2/3), beginning in December 1953. This was accomplished in a three-step operation that began with acid-leaching uranium from dry solid feed materials followed by solvent extraction processing to produce a highly pure solution of uranyl



*Plant 6 Rolling Mill Shutdown in 1971.
Plant 2/3 Ore Concentrate Campaign Completed in 1977

Figure D-1 Schematic Diagram Of The FEMP Process (After 1977*)

TABLE D-1

DELIVERIES OF URANIUM
(FY-1953 through FY-1989)

Cores and Target Elements		Metric Tons Uranium			
		Depleted	Normal	Enriched	Total
To RLO Solid		923	23,765	14	24,702
I&E		94	49,855	16,440	66,389
NPR			32	4,083	4,115
	Total	1,017	73,652	20,537	95,206
To SRP Solid			13,105		13,105
I&E – Mark VII			4,065		4,065
Mark VB			7,109		7,109
Mark VE				2,159	2,159
Mark 30				2,241	2,241
Mark 31		4,766			4,766
Mark 15		17,168			17,168
Mark 25				198	198
			15		15
	Total	21,934	24,294	4,598	50,826
Total Cores & target Elements		22,951	97,946	25,135	146,032
Intermediate Products					
UO_3 to Cascades at Paducah (PAD)		274	33,995	786	35,055
UO_3 to Allied General Nuclear (AGNS)			137		137
U_3O_8, UF_6 and UF_4 to Portsmouth				60	60
Derbies to Y-12		7,943	24		7,967
Metal to Rocky Flats		4,951			4,951
NPR/N-Reactor ingots to RMI			239	10,203	10,442
	Total	13,168	34,395	11,049	58,612
Total Deliveries		36,119	132,341	36,184	204,644

nitrate (UNH). The final step was the conversion of pure UNH solution to UO_3 by thermal decomposition. Plant 2/3 was shut down in 1962, but limited operations were resumed within one year and continued intermittently until 1972, when the concentrate conversion campaign was started. During this five-year campaign, UO_3 product was shipped to the Paducah Gaseous Diffusion Plant instead of advancing to the Green Salt Plant (4) to support uranium metal production.

Plant 4 began operating in October 1953 for converting UO_3 that was either produced in Plant 2/3 or received from offsite to uranium tetrafluoride (UF_4), commonly called green salt, by a two-step operation. In the first step, UO_3 was reduced by hydrogen to form uranium dioxide (UO_2), which was then converted to green salt using anhydrous hydrofluoric acid in the second step. Green salt was also produced in the Hexafluoride Reduction Plant (7) by a direct process that reduced uranium hexafluoride (UF_6) by hydrogen to form UF_4. Plant 7 operated for only three years, beginning in June 1954, to supplement the supply of green salt produced by Plant 4 in order to meet the peak metal demands of the mid-1950s. Green salt product was the source material for making uranium metal derbies in the Metals Production Plant (5) beginning in May 1953.

The Scrap Recovery Plant (8) began operations in November 1953 for upgrading process residues to a form suitable for uranium recovery in Plant 2/3. Process residues were numerous forms of low-assay uranium materials that were generated by all production operations. Examples include MgF2 slag, sump filter cakes, dust collector materials, incinerator ash, and off-specification UO_3 and UF_4. Low-grade metal scrap that was unacceptable for recycling via remelting was furnaced to black oxide (U_3O_8). After screening, the fine material fraction became acceptable feed for Plant 2/3 operations and the coarse material fraction was further oxidized in a furnace.

1.2 METAL PRODUCTION AND FABRICATION OPERATIONS

Plant 5 converted UF_4 into uranium derby metal by a thermite reduction process using magnesium metal granules. Derbies, so named because they were in the shape of a man's hat, weighed as much as 370 pounds. By-product magnesium fluoride (MgF_2) slag was generated in substantial quantities by the reduction process. About half of the slag generated was milled for reuse as refractory liner in metal reduction pots. Surplus slag either underwent chemical treatment for uranium recovery or was discarded to the waste pits, depending upon the isotopic enrichment.

Most derbies were cast into ingots along with high purity recycle metal scraps, either in Plant 5 or in Plant 9, depending upon the isotopic enrichment. Dimensions of cylindrical ingots were sized to the

specific end-use configurations required by the reactor sites. As-cast ingots were cropped by sawing approximately 2 inches from the top section to remove shrinkage cavities and impurities that rose to the top of the melt during solidification. Cropped ingots were sent to the Special Products Plant (9) for center-drilling and surface machining. Uranium alloy produced for DOD applications were in a slab casting configuration. High-purity derbies were also shipped to other DOE sites after surface cleaning was performed.

In Mid-1952, the Rolling Mill and Machining Areas of the Metals Fabrication Plant (6) became operational for fabricating cropped ingots into finished uranium cores. Cylindrical cropped ingots having a diameter of 6-8 inches and 60 inches length were heat treated prior to the rolling mill operation. Equipment in this operation consisted of an ingot furnace, blooming mill with reversing rolls, shearing devices, molten salt heat treating furnace, and conveyors. The blooming mill operation produced an oval billet having nominal dimensions of 1¾ inch x 2 ¼ inch. After shearing and heat treating, the oval billets advanced to a six-stand finishing mill for machining into rod stock having standard diameters in the range of 1 to 2 inches. In 1971, the rolling mill operation was shut down and all machined ingots were heat treated in Plant 6 before they were shipped to RMI Company for extrusion into tubes.

After straightening, the rod stock was transferred to the Machining Area for cutting into sections, center drilling, and surface machining to close tolerances specified for the final cores. The Machining Area had six automatic bar machines, four turret lathes, a degreasing and pickling facility, and press for compacting machining chips and turnings into briquettes. After final inspection, these final products were shipped to the user sites. Cores that failed to meet the rigorous quality standards were recycled through remelt operations in Plant 5. In 1962, the multi-station Cross Transfermatic Machine was installed and significantly increased the productivity of core machining operations.

1.3 PROCESS AND OPERATIONAL CHANGES

One of the earliest productivity improvements resulted from the application of fluidization process technology in the Green Salt Plant (4) during the late 1950s. This innovative technology greatly increased the heat transfer rate and contact between gases and solids in the reduction of uranium trioxide to the dioxide using hydrogen. Another improvement was the use of costly exotic metals in the construction of ribbon-screw conveyors in the hydrofluorination process that converted uranium dioxide to green salt. This greatly reduced the corrosive effects that previously occurred with other metals, and resulted in higher on-line performance and product consistently meeting acceptance standards.
The Reduction-Oxidation-Reduction (ROR) process was developed in 1961, as a method for increasing

the reactivity and conversion of UO_3 recycled from Hanford. In this process, UO_3 underwent the standard reduction process step to form UO_2, but not the subsequent hydrofluorination step to produce UF_4. This process is described in Attachment 1, Section 4.3 of this Appendix.

Significant operational changes were made in the early 1960's in Plant 2/3 as a result of process technology improvements. The Low-Acid Flowsheet eliminated the need for complex and elaborate equipment previously required for recovering nitrate values contained in wastewater. The Slag Leach recovery operation was implemented to recover uranium contained in surplus magnesium fluoride slag generated in the derby production process. The development of procedures and specialized equipment necessary to process this difficult material was a major contribution to the overall efficiency of plant operations.

With the cessation of operations in Plant 2/3 in 1962, limited activities were initiated to use part of the plant's facilities for recovering normal uranium process residues that had accumulated in the inventory. This operation became known as the Supplemental Recovery Facility (SRF), whose product was a solution of uranyl nitrate that was shipped to the Weldon Spring Refinery located in Missouri. When that site was closed in 1966, full operations were slowly implemented in Plant 2/3 to further reduce the sizable inventory of uranium residues and returning the uranium content to the production stream. By 1968, the conversion of the residue inventory to Refinery feeds was accomplished on a scale that surpassed all previous year totals. Residues that had previously required two runs for recovery could be recovered in one run and those requiring three runs were accomplished in two runs.

During the 1970s, Fernald processed 77.3 million pounds of uranium contained in the DOE stockpile of ore concentrates to uranium trioxide in Plant 2/3 for use by the Paducah Gaseous diffusion Plant.

In the metal production and fabrication plants (5,6 and 9), the focal point for productivity improvements was improving production yields in the manufacture of derbies, ingots, and machined cores. This objective was accomplished not only by achieving high on-line performances, but also through consistently meeting high purity standards for these products. Uranium fabrication scraps of high purity were remelted into new ingots. The Zirnlo process was developed and implemented in Plant 9 in 1963 for removing zirconium and copper metal claddings from reject uranium fuel elements for recovery uranium. About the same time, the highly-automated Cross-Transfermatic Machine was installed in Plant 6 to serve the multifunctional core machining operations. This machine was capable of performing the functions of exterior surface machining, interior surface reaming or grinding, and end facing of up to eight cores at the

same time. Previously, each of these functions was performed one at a time for each core in a manpower intensive effort, requiring a large number of machining lathes. Requirements for both equipment and manpower were greatly reduced, while production throughputs and performance yields sharply increased.

Late in 1964, the first production of 1.95 percent enriched uranium billets for Hanford was performed under closely controlled conditions to ensure nuclear criticality safety. Three different billet sizes were produced containing two different alloy compositions. Again, the unique blend of Fernald's technical expertise with skilled production workers adapted to the ever-changing demand by the user sites for different product metal configurations, dimensions, and isotopic assays. During the late 1970's, Fernald also played a major role in the development of the titanium-uranium alloy and manufacture of demonstration quantities of depleted uranium penetrators for the military.

ATTACHMENT D.1

DESCRIPTION OF FEMP SITE PROCESSES

DESCRIPTION OF FEMP SITE PROCESSES

The production processes at the FEMP were conducted in ten production plants, each having a specific mission that supplied the succeeding plant with an intermediate product for further processing until the eventual uranium product form was produced. Detailed descriptions of each plant process, production activity, and significant events are presented in this Attachment, as follows:

Section 1.0	Plant 1 Sampling
Section 2.0	Plant 2/3 Ore Refinery
Section 3.0	Pilot Plant and Plant 7 Uranium Hexafluoride Operations
Section 4.0	Plant 4 Green Salt
Section 5.0	Plants 5 and 9 Metal Production
Section 6.0	Plants 6 and 9 Metal Fabrication and Machining
Section 7.0	Pilot Plant Other Pilot Plant Uranium Operations
Section 8.0	Plant 8 Scrap Recovery
Section 9.0	Plant 9 Other Plant 9 Uranium Operations
Section 10.0	Qualitative Assessment of Dust Potential in Process Operations

1.0 SAMPLING (PLANT 1)

In December 1953, Plant 1 became operational, and soon thereafter, was designated the official AEC sampling station for determining uranium and isotopic assays of uranium ores and concentrates. Plant 1 functioned primarily to receive, weigh, sample, and store feed materials from offsite sources and process residues generated from onsite production operations. Most materials were received in 55-gallon steel drums. The process consisted of drying, milling, sampling, and analyzing, as necessary, for process control and accountability of nuclear materials. Plant 1 was considered an operations support facility and not a mainline production plant.

In 1965, the FEMP became the official receiving station for uranium compounds assaying up to 5.0 percent U-235 furnished by licensees. With the start-up of enriched uranium operations in Plant 2/3 in 1966, over 1,500 safe mass batches of up to 10 percent U-235 were prepared for the Drum Digestion system. In 1967, the limit was reduced to 5 percent U-235 in anticipation of the start-up of the Safe Geometry Digestion system in 1970. This system depicted in Figure D.1-1 was inherently safe by design for processing enriched materials assaying up to 10 percent U-235.

An isotopic verification facility was installed in 1972 at the Enriched Warehouse (Building 71) of Plant 1 as a measure for enhancing the capability of controlling enriched uranium received from offsite sources. The unit was capable of determining the isotopic consistency of materials within +/- 0.5 percent U-235.

In 1972, approximately 20,000 drums of uranium ore concentrates and residues were shipped from the Weldon Spring site for storage on the Plant 1 pad. Upon completion of the transfer, the remaining AEC stockpile of ore concentrates at Grand Junction were sent to the FEMP for long-term storage.

Other operations included milling of enriched and depleted uranium byproduct slag from Plant 5, burning waste oil, drum reconditioning; baling scrap metal drums, and screening, milling, and packaging enriched uranium dioxide for offsite shipment. Packaging enriched materials for offsite shipment became a significant activity in 1974, as oxide products from both the Plant 2/3 evaporator/calciner and the Hallam fuel recovery operations became available for shipment to the Portsmouth Gaseous Diffusion Plant.

In 1975, enriched uranium pellets assaying 9.58 percent U-235 from the disassembly of an unirradiated reactor (PM3A) fuel core were milled, screened, and shipped to the Portsmouth Gaseous Diffusion Plant as feed material to the cascades.

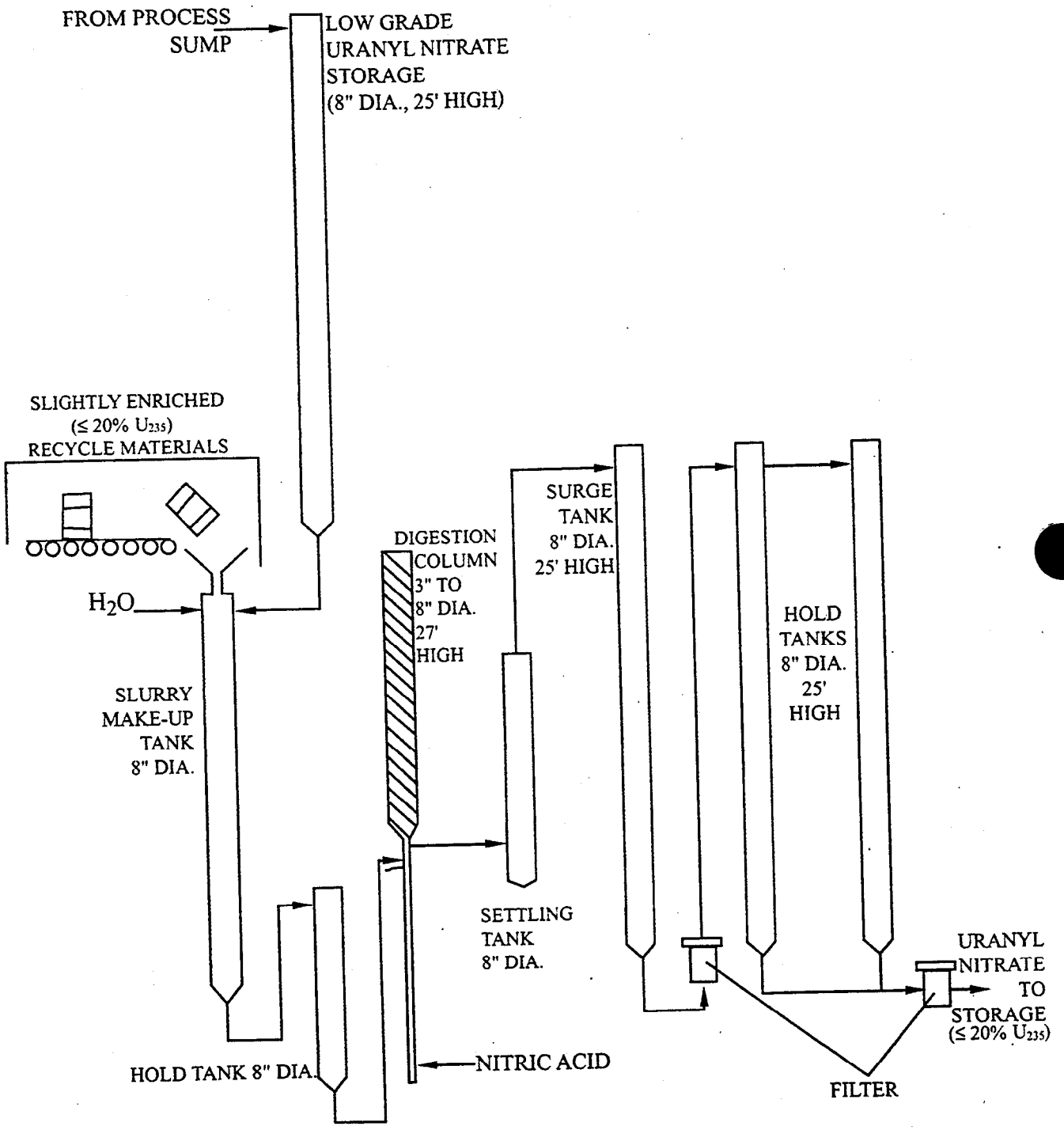


Figure D.1-1 Safe Geometry Digestion System

2.0 ORE REFINERY (PLANT 2/3)

The FEMP production process began with the conversion of uranium feed materials and recycled process residues to pure UO_3 in the Ore Refinery Plant (2/3). The original design of the Ore Refinery was based upon the annual receipt of 4570 MTU of uranium ores and concentrates. In 1956, the plant capacity was increased to 9072 MTU per year. Permanent concrete shielding was provided around appropriate equipment on the north side of the digestion and extraction areas for processing high-radium uranium ores. Unshielded operations were conducted in similar equipment on the south side for processing low-radium uranium ore concentrates. Similarly, concrete shielding was provided in the Raffinate Treatment operations for processing high-radium raffinate for silo storage. Purified UNH solution produced by the extraction operation on each side was combined in the denitration area since radium had already been removed in the raffinate.

2.1 PRODUCTION HISTORY

Operations commenced in December 1953, when the first UO_3 product was packaged. The 37-year history of UO_3 production in Plant 2/3 is presented in Table D.1-1. It should be noted that the production total for FY-1976 is for 15 months, when the government changed the basis for the fiscal year start date from July to October 1st.

2.2 PROCESS OPERATIONS

The conversion of uranium feed materials to pure UO_3 was accomplished in a three-step operation designated digestion, extraction, and denitration (Figure D.1-2). Uranium contained in dry feed materials was leached in nitric acid to produce a slurry of impure uranyl nitrate (UNH). In the second step, this slurry was processed through the solvent extraction refining operation to produce high-purity UNH solution. The final step of denitration converted the pure UNH solution to UO_3 by thermal decomposition. After milling and screening, UO_3 was loaded into portable metal hoppers or drums, either for transport to Plant 4, or shipment offsite. Support areas included Nitric Acid Recovery, Raffinate Treatment, and the Refinery Sump.

The solvent extraction operation was an adaption of the PUREX Process developed at Hanford for recovering uranium and transuranic elements from spent fuel. In this process, tri-butyl phosphate (TBP) in kerosene selectively removes soluble uranium from aqueous acidic UNH solutions into the organic extract phase. After scrubbing the extract with small quantities of deionized water to remove entrained

TABLE D.1-1

TOTAL PRODUCTION (MTU)
PLANTS 2/3 – UO_3

Fiscal Year	Normal	Enriched	Depleted	Total
1952	0	0	0	0
1953	0	0	0	0
1954	642	0	0	642
1955	3288	0	0	3288
1956	5379	0	0	5379
1957	8370	0	0	8370
1958	10039	0	0	10039
1959	11540	0	0	11540
1960	12187	0	0	12187
1961	11039	0	0	11039
1962	6288	0	0	6288
1963	0	0	0	0
1964	0	0	0	0
1965	0	543	0	543
1966	196	1151	0	1347
1967	832	1003	0	1835
1968	1557	1694	0	3251
1969	665	1363	0	2028
1970	259	580	41	880
1971	574	235	0	809
1972	2395	366	0	2761
1973	3532	2	0	3534
1974	7114	0	0	7114
1975	8189	0	0	8189
1976	9752	0	0	9752
1977	1673	518	0	2191
1978	0	0	0	0
1979	0	0	0	0
1980	0	0	0	0
1981	0	103	0	103
1982	0	203	0	203
1983	0	319	0	319
1984	0	306	0	306
1985	0	145	0	145
1986	0	2	0	2
1987	0	170	0	170
1988	0	93	0	93
1989	0	0	0	0
Totals	105510	8796	41	114347

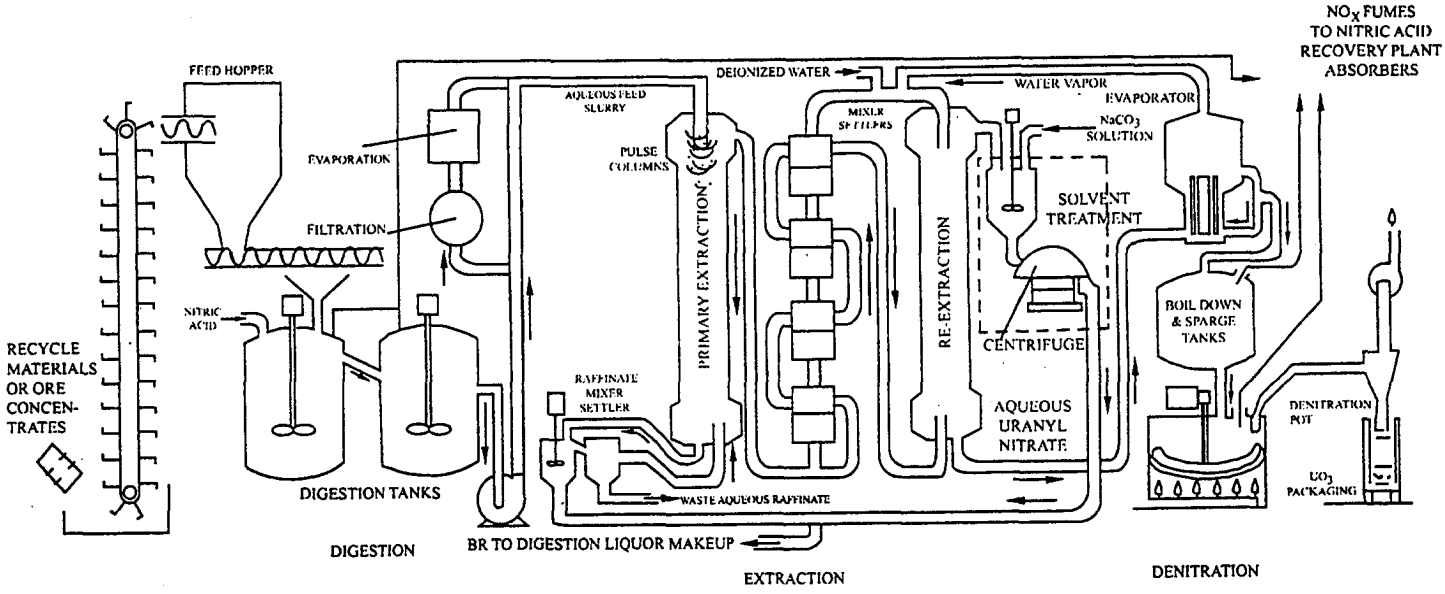


Figure D.1-2 Refinery Process Flow

impurities, the extracted uranium is recovered by contact with large quantities of non-acidic water. Perforated-plate, pulse columns were used for these operations.

2.3 SIGNIFICANT EVENTS

Plant operations were maintained on a high level during the 1950s using ores and concentrates feeds, reaching a peak of 12,187 MTU in 1960. Then, the amount of ore available to Fernald steadily decreased and it became necessary to process large quantities of low-quality feeds and process residues recycled from onsite operations. Early in 1962, Plant 2/3 was shut down and placed in standby and all uranium refining operations were consolidated at the Weldon Spring Site.

Limited operations were resumed in 1963, using selected facilities for recovering normal uranium from low-grade residues and scrap metal as impure UNH solution, which was shipped to Weldon Spring in insulated tank trucks. The use of these selected facilities was called Supplemental Recovery Facility (SRF) because the limited production provided an additional input to the consolidated refining operation at Weldon Spring. Eventually, the operation was extended to processing enriched uranium residues and scraps, and the process operation was designated E-SRF. Enriched UNH solution produced by E-SRF processing was stored in available tanks in Plant 2/3 for possible future use. Records do not indicate that enriched UNH solution was ever sent to Weldon Spring.

In May 1965, a new process called the Slightly Enriched Recovery Facility (SERF) was started to convert accumulated UNH solution from E-SRF to enriched UO_3 to meet an emerging demand. The SERF operation utilized all three process areas of Plant 2/3 (See Figure D.1-3), and continued intermittently until 1971. Enriched uranium feed assaying up to 1.25 percent U-235 were processed in 1967; the maximum permissible enrichment of 2.0 percent U-235 was produced in 1968. Operations were curtailed once again in 1970, when the facility was limited to maintaining the inventory of recoverable residues at minimal levels.

The installation of a safe-geometry evaporator/calciner system for converting high-purity enriched UNH to cascade quality U_3O_8 was begun late in 1972. Performance testing of equipment was completed in 1973, and the system became fully operational in 1974. A schematic flow diagram of the process is shown in Figure D.1-4. This operation continued through 1977, producing U_3O_8 in the isotopic range of 2.0 to 5.0 percent U-235. The product U_3O_8 was shipped to the Portsmouth Gaseous Diffusion Plant, but was eventually returned to the FEMP, because of process difficulties at Portsmouth.

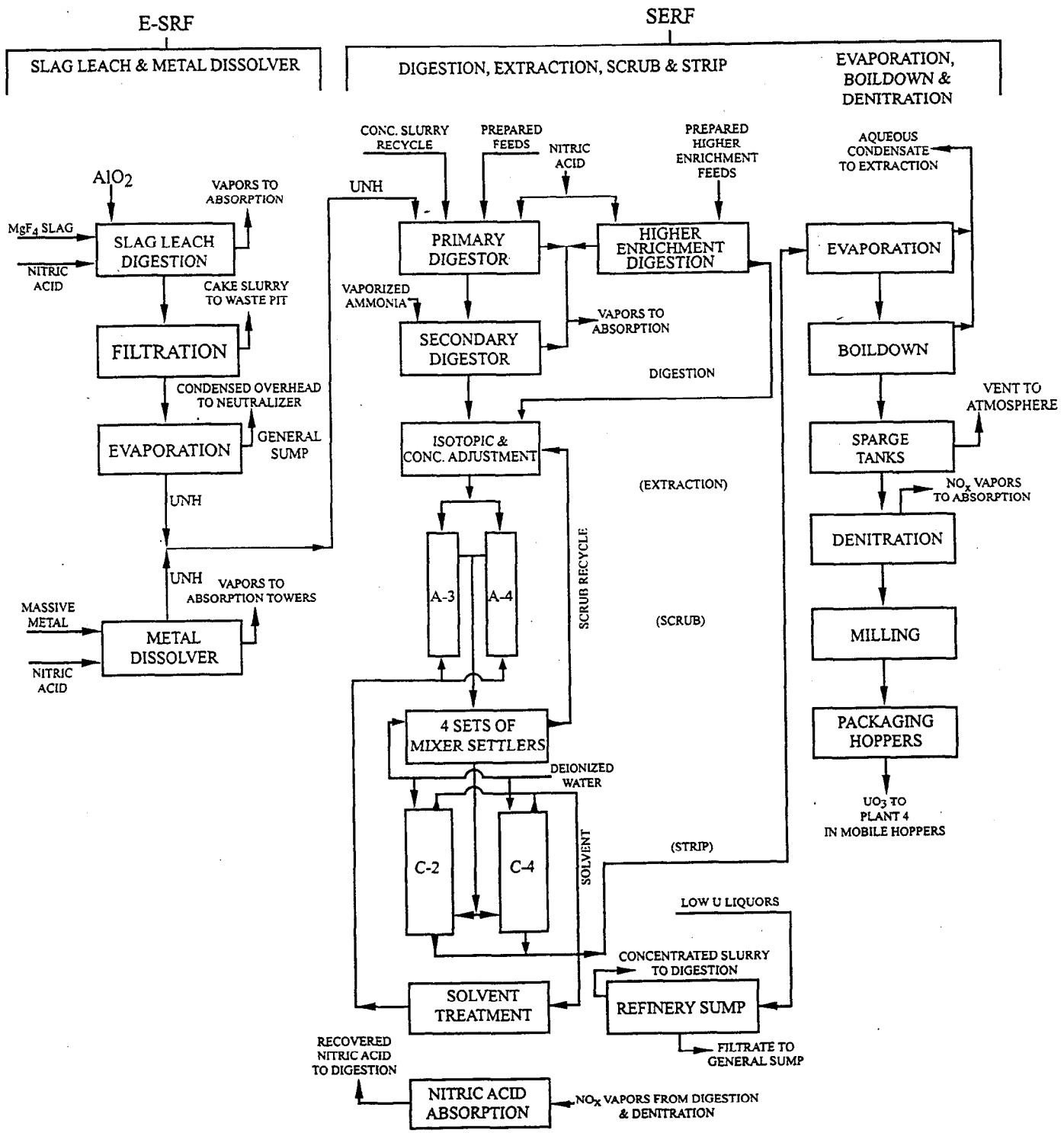


Figure D.1-3 Flowsheet, E-SRF and SERF Systems (Plants 2 and 3)

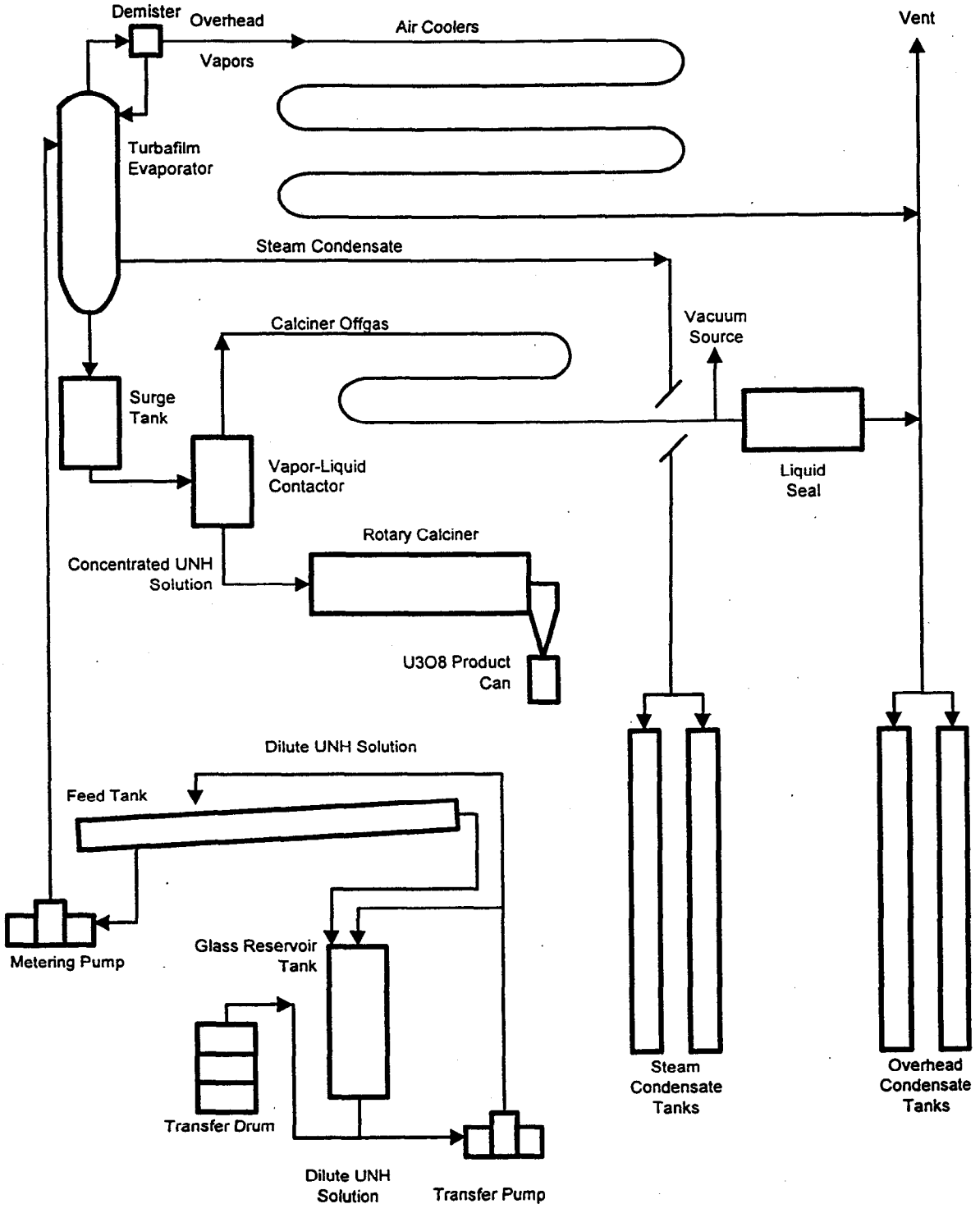


Figure D.1-4 Schematic Flow Diagram of Evaporator - Calciner

In April 1971, uranium ore concentrates from inventory were processed through Plant 2/3 for shipment of product UO_3 to the Paducah Gaseous Diffusion Plant. Operations were extended to full-scale by the start of 1973, and continued at high tonnage levels until the campaign ended in 1977. Although the small campaign of 2.0 percent U-235 conducted in May 1972 was the only exception to normal uranium processing during this period, the receipt of 470 MTU as process residues from the Paducah scrap inventory were blended with ore concentrates in 1976 until the campaign ended in 1977.

3.0 URANIUM HEXAFLUORIDE REDUCTION OPERATIONS (PLANT 7 AND PILOT PLANT)

Green salt was also produced in Plant 7 and on a smaller scale in the Pilot Plant by a direct process that reduced uranium hexafluoride (UF_6) by hydrogen to form UF_4. Plant 7 was operated for only three years, beginning in June 1954, to supplement the supply of green salt produced by Plant 4 in order to meet the peak metal demands of the mid-1950s.

3.1 PLANT 7 UF_6 TO UF_4 PROCESS OPERATIONS

The hexafluoride reduction, or UF_6 to UF_4 conversion process was identical in both Plant 7 and the Pilot Plant; only the scale and use of equipment differed. Cylinders containing UF_6 in solid form were connected to vaporizers to generate gaseous UF_6 for the reduction reaction. Hydrogen was generated by ammonia dissociation, and was mixed with the UF_6 gas in a specially designed nozzle contained within a vertical reaction tube or tower, depending on the scale. The conversion reaction proceeded rapidly at operating temperatures of about 1000 F.

Most of the solid UF_4 settled downward within the reactor tower/tube as a fine powder and was collected in a hopper. From there, the UF_4 powder was pulverized, blended, weighed, and packaged into 10-gallon cans for transfer to Plant 5.

The installed capacity of Plant 7 was 14.6 U tons per day, based on a feed rate of 300 lb UF_6 per hour split evenly between depleted and normal uranium, from two sets of four reactors each. By the end of 1955, a feed rate of 550 lb UF_6 per hour was attained, yielding an average of nearly 27 tons UF_4 per day. Typical levels of production are shown in Table D.1-2 for operations during the first half of 1956, when a monthly average of 286 MTU was attained. Plant 7 was shutdown in May 1956, with the completion of the Paducah feed plant. After remaining idle for thirteen years, all equipment was declared excess property and was sold in 1969.

3.2 PILOT PLANT UF_6 TO UF_4 PROCESS OPERATIONS

The operation of the small-scale unit in the Pilot Plant began in 1958, and was operated primarily for producing enriched UF_4 for conversion to metal. The 37-year history of UF_4 production in the Pilot Plant is presented in Table D.1-3. With the introduction of enriched uranium processing in Plant 2/3 beginning in 1965, the Pilot Plant UF_6 to UF_4 facility was also operated to produce "sweetener" for adjusting the isotopic assay of recycled materials to meet product specifications. Sweetener was the term for restoring

TABLE D.1-2

TYPICAL CONSUMPTION AND PRODUCTION OF THE HEX PLANT (U LBS.)

	Normal		Depleted	
FY-1956	UF_6 Charged	Acceptable UF_4	UF_6 Charged	Acceptable UF_4
January	193,231	157,289	628,488	585,647
February	315,035	304,818	521,846	507,785
March	333,036	229,268	597,344	583,550
April	414,738	511,894	648,772	679,549
May	223,696	241,989	0	0
Total				
(Pounds)	1,479,737	1445,258	2,396,450	2,356,531
Metric Tons	671	656	1,087	1,069
Monthly Average	135	131	272	286

TABLE D.1-3

TOTAL PRODUCTION (MTU)
Pilot Plant – UF_4

Fiscal Year	Normal	Enriched	Depleted	Total
1932	0	0	0	0
1953	0	0	0	0
1954	0	0	0	0
1955	0	0	0	0
1956	0	0	0	0
1957	0	0	0	0
1958	0	540	0	540
1959	0	995	0	995
1960	0	962	0	962
1961	0	1676	0	1676
1962	0	1619	0	1619
1963	0	1479	0	1479
1964	0	2061	0	2061
1965	0	792	0	792
1966	0	741	0	741
1967	0	348	0	348
1968	0	0	0	0
1969	0	0	0	0
1970	0	0	0	0
1971	0	0	0	0
1972	0	0	0	0
1973	0	0	0	0
1974	0	0	0	0
1975	0	0	0	0
1976	0	0	0	0
1977	0	0	0	0
1978	0	0	0	0
1979	0	0	0	0
1980	0	0	0	0
1983	0	0	0	0
1984	0	0	0	0
1985	511	111	0	622
1986	92	125	245	452
1987	0	160	382	542
1988	0	0	1642	1642
1989	0	0	0	0
Totals	603	11609	2269	14481

the fraction of U-235 that had been converted to transuranic elements and fission products in reactor site operations. A major release of1195 kg U as UF_6 occurred during a one-hour period on February 1966, when a valve was inadvertently removed. Since the material was in the 2.0 percent U-235 range, the origin was likely to have been either Oak Ridge or Portsmouth. Production activity was suspended in 1967 because sufficient sources of sweetener were available from enriched uranium received from offsite. Activity resumed in 1985, when the larger scale, upgraded facility was placed into service.

4.0 GREEN SALT (PLANT 4)

Plant 4 began operating in October 1953 for converting orange oxide (UO_3) that was either produced in Plant 2/3 or received from offsite sources to UF_4 by a two-step operation. The process is schematically illustrated in Figure D.1-5. Green salt product was the source material for making uranium metal derbies in Plant 5, beginning in May 1953.

4.1 PRODUCTION HISTORY

The 37-year history of UF_4 production in Plant 4 is presented in Table D.1-4. Most of the normal UF_4 produced was derived from orange oxide from Plant 2/3 operations, but some was derived from the Port Hope Refinery in Canada in 1957. Enriched UF_4 was produced from both onsite and offsite sources, namely, Plant 2/3 and recycle from Hanford and Savannah River. Depleted UF_4 was produced via screening and packaging green salt from onsite production in the Pilot Plant or received from the gaseous diffusion plants, primarily from Paducah.

Early production of UF_4 did not progress as rapidly as expected, although throughputs increased significantly by 1955. It was not until the production of 5,029 MTU in 1956, that the design rate of 5193 MTU was approached. Production reached the 9,000 MTU level in 1957, nearly doubling the 1956 performance, and reached a high point of 12,000 MTU in 1958. This improvement in productivity primarily resulted from the introduction of the two-stage fluid bed reactors.

4.2 PROCESS OPERATIONS

In the first processing step in Plant 4, UO_3 was reduced by hydrogen to form uranium dioxide (UO_2), which was then converted to green salt using anhydrous hydrofluoric acid in the second step. In the 2nd step, UO_2 powder was conveyed to a group of three heated, horizontal, ribbon-screw reactors arranged in a vertical stack. The vertical grouping array of equipment needed for performing both steps was called a bank. Initially, there were six banks installed on both the East and west sides of Plant 4.

To begin this production process, mobile hoppers were used to deliver orange oxide to a two-stage, stainless steel fluid bed reduction reactors that operated at about 1000 F. Dissociated ammonia (hydrogen and nitrogen) entered the bottom of the reactors through a gas diffuser plate. The combined flow of hydrogen and nitrogen was maintained to hold the UO_3 powder in suspension so that it behaved as a fluid. Partially converted UO_3 overflowed from the first reactor stage to the second where the reaction

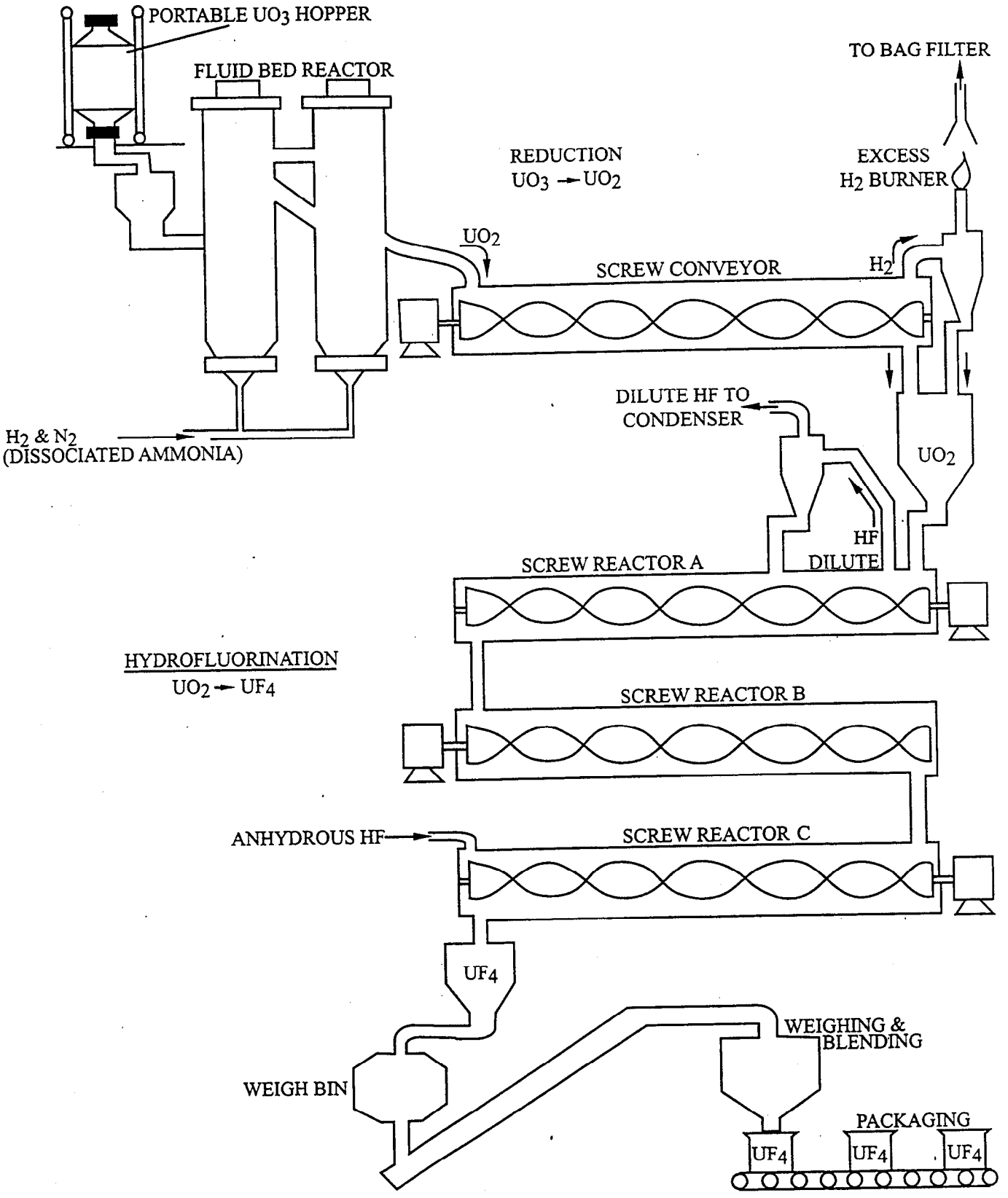


Figure D.1-5 Green Salt Process Flow

TABLE D.1-4

TOTAL PRODUCTION (MTU)
PLANT 4 – UF_4

Fiscal Year	Normal	Enriched	Depleted	Total
1952	0	0	0	0
1953	0	0	0	0
1954	1568	0	0	1568
1955	3314	0	0	3314
1956	5029	0	0	5029
1957	9358	0	0	9358
1958	11577	0	0	11577
1959	8459	0	0	8459
1960	10426	0	0	10426
1961	8966	0	0	8966
1962	7849	0	0	7849
1963	7928	1075	0	9003
1964	4145	997	0	5142
1965	3117	2888	0	6005
1966	2052	3381	107	5540
1967	2632	3283	677	6592
1968	1219	3590	1549	6358
1969	494	2327	1386	4207
1970	1009(a)	914	943	2866
1971	55	525	876	1456
1972	0	347	1028	1375
1973	0	0	2159	2159
1974	0	342	980	1322
1975	0	634	1144	1778
1976*	0	0	1276	1276
1977	0	0	1950	1950
1978	0	544	1735	2279
1979	0	0	1513	1513
1980	0	479	2059	2538
1981	0	562	2105	2667
1982	0	366	3999	4365
1983	0	1145	3599	4744
1984	0	1240	5828	7068
1985	60	1086	4292	5438
1986	0	1068	5043	6111
1987	0	280	5093	5373
1988	0	388	1387	1775
1989	0	0	0	0
Totals	89257	27461	50728	167446

with hydrogen to form a talcum-fine UO_2 powder was completed. A seal hopper prevented hydrogen from advancing with the UO_2 powder to the hydrofluorination reactors.

Each of the three hydrofluorination reactors (A,B,C) was constructed of inconel for corrosion resistance, and had dimensions of 16-inches diameter and 20-feet in length. The ribbon-screw conveyor was constructed of Hastelloy, and slowly turned the UO_2 powder as it was being conveyed. Anhydrous hydrogen fluoride (HF) gas entered at the discharge end of Screw Reactor C and flowed counter-currently to the UO_2 powder up through the Screw Reactors B and A. Later process modifications split the inlet HF gas flow to 70 percent added to Reactor C and 30 percent to Reactor B to improve the conversion and quality of UF_4 product. Excess HF was vented from the feed end of Screw Reactor A and condensed to a dilute solution of HF. Product UF_4 was weighed, blended, sampled for quality control, and packaged in 10-gallon cans for transfer to Plant 5.

4.3 SIGNIFICANT EVENTS

Recycling of "500" enriched material was started in Plant 9 in 1961, requiring complete segregation from standard normal and other enriched uranium operations. Enriched uranium designated "300" material was derived from offsite sources that had never been irradiated. Cascade withdrawals of enriched UF_6 and the variety of residues generated from its subsequent onsite processing to metal were examples of "300" material. The primary source of "500" material was byproduct UO_3 (A508) recycled from operations at Hanford for recovering transuranic elements from spent reactor fuel. After the shutdown of Plant 2/3 in 1962, sources of UO_3 for conversion to UF_4 in Plant 4 were Weldon Spring, Port Hope, Hanford, and Savannah River.

The Reduction-Oxidation-Reduction (ROR) process was developed in 1961, as a method for increasing the reactivity and conversion of UO_3 recycled from Hanford. In this process, UO_3 underwent the initial reduction process step to form UO_2, but not the subsequent hydrofluorination step to produce UF_4. Instead, the intermediate UO_2 powder was oxidized in heated air to form black oxide (U_3O_8), which was

of the black oxide formed, compared with UO_2, resulting in higher yields and quality of UF_4 product. The ROR process was fully implemented in Plant 4 with the conversion of two reactor banks in 1962.

Also in 1962, the WINLO process was started in Plant 8 for recovering uranium from high-grade process residues as UF_4. The name of this process was derived from the joint development effort between the Winchester National Laboratory at Boston and NLO at Fernald. Because WINLO was a wet-way process that used dilute HF, hydrated (3/4 H2O) green salt was produced instead of anhydrous UF_4 from the

standard Plant 4 process. Since the presence of water in UF_4 was detrimental to the metal reduction process for making derbies in Plant 5, one reactor bank was converted in 1962 for use in dehydrating WINLO green salt.

The production of large quantities of enriched UF_4 started in 1963, with UO_3 recycled from Hanford ("A508" material). At various times, the plant processed combinations of WINLO green salt for dehydration, normal UO_3 from Weldon Spring and Port Hope, UO_3 recycled from Hanford and Savannah River, and "300" and "500" enriched UO_3 from a scrap processing campaign at Weldon Spring. Complete clean outs of process reactor banks were required between the specific campaigns of these different source materials to maintain nuclear criticality control , accountability of uranium values, and segregation of isotopic enrichments.

Starting in 1965, enriched UO_3 produced from the Refinery SERF process was used as a feed material. Enriched UO_3 was also received from Hanford during the same year. Normal UO_3 processed in 1965 came from Weldon Spring and Port Hope. These receipts continued through 1971. Plant 4 was operated for only four months in 1971, and two months in 1972 on enriched UF_4 production. The plant was idle during all of 1973.

In April 1974, production demands commenced on enriched UF_4 for the Hanford N-Reactor production stream and continued through June. Another enriched campaign was conducted during the period from January through April 1975, and remained idle following this campaign through 1977. A small campaign was conducted in 1978, but was shutdown in 1979. Operations were restarted in 1980, and continued intermittently through 1989.

5.0 METAL PRODUCTION (PLANTS 5 & 9)

Plant 5 is comprised of the Reduction Area where UF_4 was converted into uranium derby metal and the Casting Area where derbies and other forms of high-grade metal scraps were cast into ingots. Derbies, so named because they were in the shape of a man's hat, weighed as much as 370 pounds. Both processes are illustrated in Figure D.1-6. Each area had its own distinct support components, including a slag liner and milling operation for supporting metal reduction and a Graphite Machining Shop to support casting operations. Major components of the Reduction process included eleven jolters, five filling machines forty-four reduction furnaces, and two derby breakout stations. The operational steps for producing derby metal are described in Section 5.1.1.

The Casting area is where derbies and recycle scrap metal in the form of ingot top crops, briquettes, crushed elements, and other bulk forms of high-grade metal scraps were cast into ingots. Casting Area equipment included twenty-eight vacuum induction furnaces for melting derbies and other high-grade uranium metal scraps into ingots. Auxiliary equipment included crucible and mold coating equipment; crucible burnout and ingot separation stations; and saws for cropping the top of cast ingots.

Sufficient quantities of cleaned derbies and metal scrap were charge into a coated graphite crucible to produce a product ingot of the desired dimensions and weight. Loaded crucibles were placed into the top furnace and heated for about 1.5 hours to approximately 2500 F, at which the molten uranium mass is ready to pour. A closure plug in the bottom of the crucible was then sheared to permit the molten metal to flow into a heated, coated, graphite mold in the bottom furnace. The bottom furnace temperature was controlled to allow the ingot to solidify from the bottom to top.

Crucibles were prepared for reuse by inverting them in a controlled facility for burning any residual uranium adhering to the interior. Molds were removed from cast ingots after cool down and cleaned for reuse. During the controlled solidification of castings, oxides and carbon impurities floated on the surface of molten uranium and rose to the top of the ingot. Such impurities were removed from cast ingots by cropping a few inches from the top section using mechanical saws; the sawed section was identified as a top crop.

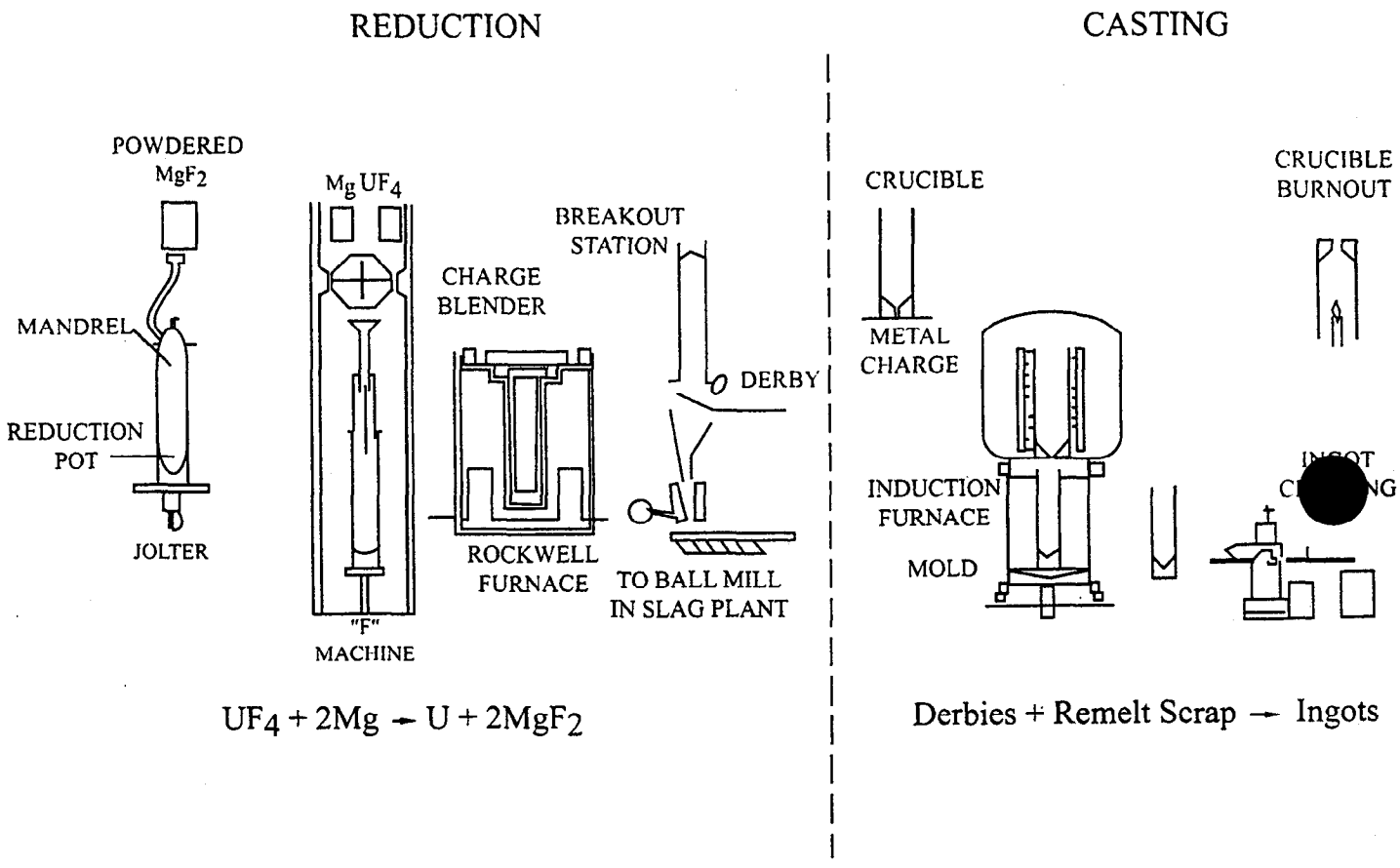


Figure D.1-6 Metal Production and Foundry Process in Plant 5

5.1 PRODUCTION HISTORY OF PLANTS 5 & 9

Production operations in Plant 5 began in May 1953, and Plant 9 in October 1954. The 37-year history of derby production and ingot casting in Plant 5 is presented in Tables D.1-5 and D.1-6, respectively. Green salt from Plant 4 was the main feed to Plant 5 from the startup in 1953 through 1962. Some enriched UF_4 came from the Pilot Plant and Plant 7 Uranium hexafluoride Plants during that period. Between 1963 and 1966, UF_4 produced at the Weldon Spring site was also converted to derby metal in Plant 5.

Beginning in 1967, depleted UF_4 assaying 0.14 percent and 0.20 percent U-235 was obtained from Paducah inventory to support both the manufacture of Mark 30/31 target element cores for Savannah River and for shipment of derbies to the Oak Ridge Y-12 Plant. The Paducah UF_4 inventory supported these production streams through September 1976. During this period, all normal and enriched UF_4 used in the reduction process was produced in Plant 4. The use of enriched UF_4 for derby metal production started in 1958.

Reduction of depleted UF_4 to metal commenced in Plant 9 during 1966. In 1968, all depleted derby production operations were consolidated in Plant 5 because of cutbacks in production tonnages. Production was reduced by over 1,000 MTU annually both in 1969 and 1970. A total of 1,344 MTU derbies of all isotopic levels were produced in 1971. The last normal uranium derby was produced in that year, ending nineteen consecutive years of their manufacture.

Early in 1972, derby production nearly doubled the 1971 level, primarily from an increase in the isotopic level from 0.14 percent to 0.20 percent U-235 for Savannah River. Annual fluctuations in production activity occurred for the next three years until it stabilized at 1,300 MTU in 1976.

Ingot casting production in Plant 9 for the same period is presented in Table D.1-7. Production of normal uranium solid ingots rose steadily to 9,500 MTU in 1955, and increased to over 12,000 MTU in 1956. Trends in annual production levels and isotopic levels of product ingots in succeeding years followed the

5.1.1 Metal Reduction Operations in Plants 5 & 9

Uranium derby metal was produced from UF_4 by a thermite reduction process using magnesium metal granules. This reaction takes place in a closed steel furnace pot, which is lined with compacted finely milled magnesium fluoride (MgF_2) slag prepared in the jolter operation. The compacted slag liner served as a refractory layer for protecting the furnace pots from the intense heat of the thermite reaction. Green

TABLE D.1-5

TOTAL PRODUCTION (MTU)
PLANT 5 - DERBIES

Fiscal Year	Normal	Enriched	Depleted	Total
1952	0	0	0	0
1953	45	0	0	45
1954	2099	0	0	2099
1955	5824	0	0	5824
1956	8459	0	0	8459
1957	6113	0	0	6113
1958	6260	489	0	6749
1959	6881	878	0	7759
1960	9704	882	0	10586
1961	7052	1418	0	84170
1962	6782	1781	0	8563
1963	7655	2588	0	10243
1964	4080	3568	0	7648
1965	2991	3441	0	6432
1966	2018	3054	94	5166
1967	2756	3547	236	6539
1968	1255	3435	660	5350
1969	95	2578	1344	4017
1970	1974	261	650	2885
1971	172	205	967	1344
1972	0	225	992	1217
1973	0	170	1969	2139
1974	0	362	954	1316
1975	0	325	797	1122
1976	0	140	1564	1704
1977	35	219	1525	1779
1978	0	291	1848	2139
1979	0	272	1346	1618
1980	0	217	1806	2023
1981	0	588	2020	2608
1982	0	682	3477	4159
1983	0	1085	3717	4802
1984	0	1054	5237	6291
1985	218	1111	3746	5075
1986	215	1010	4981	6206
1987	0	346	4260	4606
1988	0	305	2362	2667
1989	0	0	23	23
Totals	82683	36527	46575	165785

TABLE D.1-6

TOTAL PRODUCTION (MTU)
PLANT 5 – INGOT CASTING

Fiscal Year	Normal	Enriched	Depleted	Total
1952	0	0	0	0
1953	90	0	0	90
1954	3976	0	0	3976
1955	9528	0	0	9528
1956	12037	0	0	12037
1957	12680	0	0	12680
1958	12727	0	0	12727
1959	13365	0	0	13365
1960	16708	0	0	16708
1961	12691	0	0	12691
1962	12865	0	0	12865
1963	14285	0	0	14285
1964	11655	0	0	11655
1965	10234	0	0	10234
1966	6498	1376	67	7941
1967	5266	5271	432	10969
1968	2503	4703	2248	9454
1969	192	3906	2540	6638
1970	3762	394	1269	5425
1971	435	102	1838	2375
1972	0	51	1632	1683
1973	0	32	3260	3292
1974	5	186	1525	1716
1975	0	132	1041	1173
1976*	0	61	2080	2141
1977	35	61	2114	2210
1978	0	58	1910	1968
1979	0	0	1386	1386
1980	0	0	1989	1989
1981	0	0	2047	2047
1982	0	0	3732	3732
1983	0	610	3954	4564
1984	0	239	3694	3933
1985	691	125	3743	4559
1986	206	0	4104	4310
1987	0	0	4501	4501
1988	0	0	3109	3109
1989	0	0	883	883
Totals	162434	17307	55098	234839

TABLE D.1-7

TOTAL PRODUCTION (MTU)
PLANT 9 – INGOT CASTING

Fiscal Year	Depleted	NPR Normal	Enriched	I&E	Total
1952	0	0	0	0	0
1953	0	0	0	0	0
1954	0	0	0	0	0
1955	0	0	0	0	0
1956	0	0	0	0	0
1957	0	0	0	0	0
1958	0	0	0	732	732
1959	0	0	0	1251	1251
1960	0	0	0	1388	1388
1961	0	0	0	2364	2364
1962	0	0	0	2663	2663
1963	0	0	0	3660	3660
1964	0	0	0	5297	5297
1965	0	0	0	5361	5361
1966	0	0	1197	3366	4563
1967	31	0	1227	0	1258
1968	0	0	690	0	690
1969	0	0	778	0	778
1970	0	0	499	0	499
1971	0	0	422	0	422
1972	0	0	599	0	599
1973	0	0	452	0	452
1974	0	37	993	0	1030
1975	0	0	697	0	697
1976	0	0	304	0	304
1977	0	0	381	0	381
1978	0	0	480	0	480
1979	0	0	604	0	604
1980	0	0	380	0	380
1981	0	0	796	0	796
1982	0	0	974	0	974
1983	0	0	1366	0	1366
1984	0	0	1516	0	1516
1985	0	48	1026	0	1074
1986	0	179	1461	0	1640
1987	0	10	735	0	745
1988	0	0	394	0	394
1989	0	0	0	0	0
Totals	31	274	17971	26082	44358

salt and magnesium granules, totaling about 500 pounds were blended and charged to the cavity of the lined pot in the filling machines. The pot was capped with slag, sealed, and heated in stepwise in an electric resistance furnace to a temperature range of 1350 F to 1500 F. Controlled stepwise heating was necessary to prevent pre-ignition of the UF_4/Mg charge. When the temperature range was reached, the charge spontaneously reacted to produce the derby; internal pot temperatures reached the 3000 F range.

About five minutes after the reaction occurred, the pot was removed from the resistance furnace and allowed to cool in ambient air for at least one hour. After air-cooling, the pot was transferred to a water-cooling tank to lower the temperature to several hundred degrees for subsequent safe handling. The contents were then removed by inverting the pot in an enclosed derby breakout station. The uranium metal derby was separated, cleaned, weighed, identified, and transferred to the Casting Area. The nominal weight of a derby ranged from 300 to 370 pounds, depending upon the density of the UF_4 feed.

Byproduct MgF_2 slag was generated in substantial quantities by the reduction process. About half of the slag generated was milled for reuse as refractory liner in metal reduction pots. Surplus slag either underwent chemical treatment for uranium recovery or was discarded to the waste pits, depending upon the isotopic enrichment.

5.1.2 Ingot Casting Operations in Plants 5 & 9

Most derbies were cast into ingots along with high purity recycle metal scraps, either in Plant 5 or in Plant 9, depending upon the isotopic enrichment. Enriched ingots for Savannah River and all normal and depleted uranium ingots were cast to a cylindrical configuration in Plant 5. Dimensions of these ingots were sized to the specific end-use configurations required by the reactor sites.

Ingots produced for Savannah River were from derbies produced in Plant 5, metal recycle from Plant 9 machining, and briquettes made from machining chips in Plant 6. Ingot sizes varied from 7 to 10-inches in diameter and 23 to 40-inches in length, and weighed up to 1,400 pounds.

Enriched uranium ingots for the Hanford N-Reactor were cast in Plant 9. A schematic flow diagram of the entire process for producing inner and outer billets is shown in Figure D.1-7. Ingots were cast up to 13-inch diameter, 38-inch length, and weight up to 2,000 pounds. Feed materials for producing N-Reactor ingots consisted of enriched derbies from Plant 5 together with metal recycle from Plant 9 machining. As-cast ingots were cropped by sawing approximately 2 inches from the top section to remove shrinkage cavities and impurities that rose to the top of the melt during solidification.

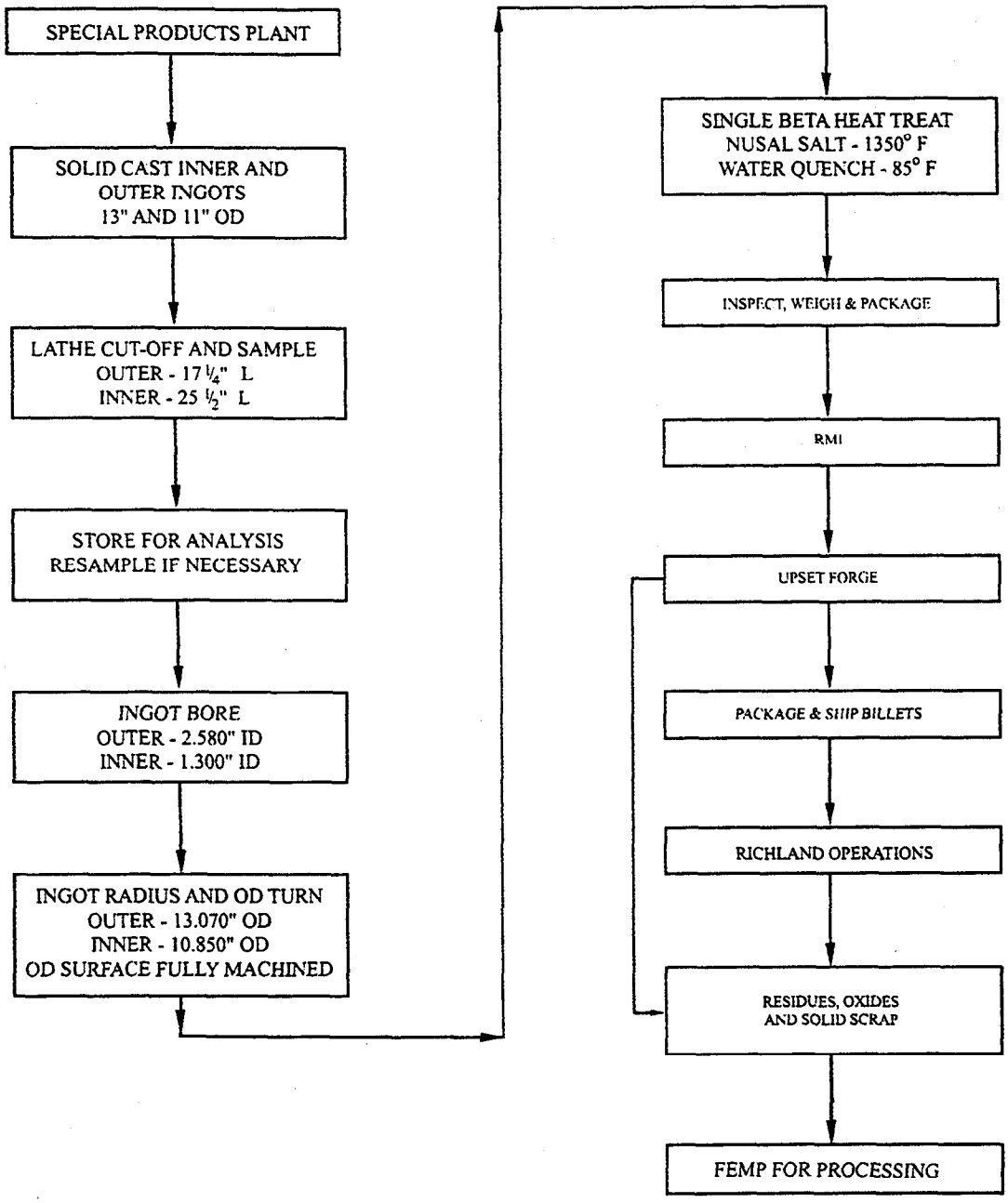


Figure D.1-7 Process Flow for NPR/N-Reactor Mark IV Inner and Outer billets by Upset Forge Route

Cropped ingots were sent to the Rolling Mill Area of the Metal Fabrication Plant (6) until it was shut down in 1971, and thereafter, to the Special Products Plant (9) for center-drilling and surface machining. At that time, all machined ingots were sent to RMI Company after they were heat-treated. Ingots for the N-Reactor production stream were upset-forged to produce a billet for co-extrusion at Hanford. Ingots for Savannah River were extruded into tubes at RMI and returned to the FEMP for fabrication into target element cores.

5.2 SIGNIFICANT EVENTS IN PLANTS 5 & 9

During 1954 through 1958, a special program was conducted for supplying the Oak Ridge Y-12 Plant with 4,700 MTU ingots alloyed with 10 percent molybdenum.

Hollow type, normal ingots with an OD of 7-3/8ths-inches and ID of 2-inches were produced in 1958 for the Mark V-B program at Savannah River. In the same year, production of enriched uranium solid type ingots for the Interior and Exterior (I&E) Core program at Hanford. Enriched uranium ingots having an 11-inch OD were produced for the early phases of the N-Reactor program at Hanford in 1959 and 1960.

Recycling of enriched "500" material was begun in Plant 9 during 1961, and required rigid security and material control practices. A dry-blend process for isotopic adjustment of enriched uranium metal was started in 1961. It succeeded in allowing the remelt of various enrichments of metal scraps in Plant 9 casting operations.

In 1963, the ingot diameter for the N-Reactor program was changed from 7 to 8 inches, and later to 11 and 13 inches. Also, the Mark V-E program for Savannah River required the casting of 8-inch OD ingots for the inner and 9-inch OD for the outer elements. In 1964, crucible charges were standardized for ingot production for both Hanford and Savannah River.

Cuts in production occurred in 1965, resulting in the consolidation of operations for casting inner and outer (I&E) ingots from Plant 9 to Plant 5. Further cuts in production were mandated in 1967, and were continued through 1971. These reductions not only were accompanied by changes in product specifications and isotopic levels, but also implemented the upset forge process at RMI Company that redirected the transfer of forged billets to Hanford instead of being returned to Fernald for final fabrication.

In 1966, Savannah River replaced Mark V-E with the Mark V-R, requiring a change in the isotopic level in their enriched uranium program. The depleted uranium (0.14 percent U-235) Mark 30 program was started for Savannah River in 1967, and required the casting of 8, 9, and 10-inch OD ingots. This program was replaced by the 0.20 percent U-235 Mark 31 program in 1972, and increased significantly in subsequent years. In 1972 and again in 1982, ingots were cast for the 1.10 percent U-235 Mark 15 test program at Savannah River.

In 1975, limited quantities of special flat castings were produced for Rocky Flats and uranium-titanium alloy castings were produced for applications in DOD programs. High-purity derbies were also shipped to other DOE sites after surface cleaning was performed.

6.0 METAL FABRICATION AND MACHINING (PLANTS 6 & 9)

The mission of fabricating normal uranium ingots received from Plant 5 into rod stock for machining into finished uranium cores became operational in May 1953. Metal fabrication and machinery operations were conducted in Plants 6 and 9. In Plant 6, operations were conducted in the Rolling Mill and Machining Areas. Equipment was also provided for heat treating and quality inspection of finished products. A process flow diagram of the original metal fabrication and machining operations conducted in Plant 6 is illustrated in Figure D.1-8. Plant 9 Machining operations began in 1957. The 32-year history of metal fabrication and machining the variety of normal, enriched, and depleted uranium metal products in Plants 6 and 9 is shown in Figure D.1-9.

A process flow diagram for the production of normal uranium inner and outer (I&E) cores for Hanford is shown in Figure D.1-10. The same steps were used for producing enriched uranium I&E cores, but, the dimensions were slightly different than for normal uranium cores. Many core configurations were specified for the Savannah River production stream over the years.

6.1 PRODUCTION HISTORY

Upon completion of start-up tests in mid-1952, the Plant 6 Rolling Mill began operations with 5-inch normal uranium ingots at a rate of approximately 500 MTU per month. This production rate was established to support an average monthly shipping schedule of 381 MTU finished cores to the reactor sites at Hanford and Savannah River. The 37-year history of rolling cast ingots into rod stock in Plant 6 is presented in Table D.1-8. In 1954, the mill began rolling 7-inch diameter normal uranium ingots to support core deliveries to the reactor sites at Hanford and Savannah River. The first enriched uranium ingot was rolled into rod stock in 1958. A chronology of ingot rolling operations through 1967 is summarized in Table D.1-9.

The effective production of normal uranium rods peaked in 1960, with the production of 17,255 MTU; another 1,277 MTU enriched uranium rods were produced in the same year for a total annual production of 18,532 MTU. The 37-year histories of fabricating normal, enriched, and depleted cores and target elements in Plants 6 and 9 are presented in Tables D.1-10 and D.1-11, respectively. Rod sizes varied considerably over the years, depending upon specifications established by each reactor site for finished fuel elements.

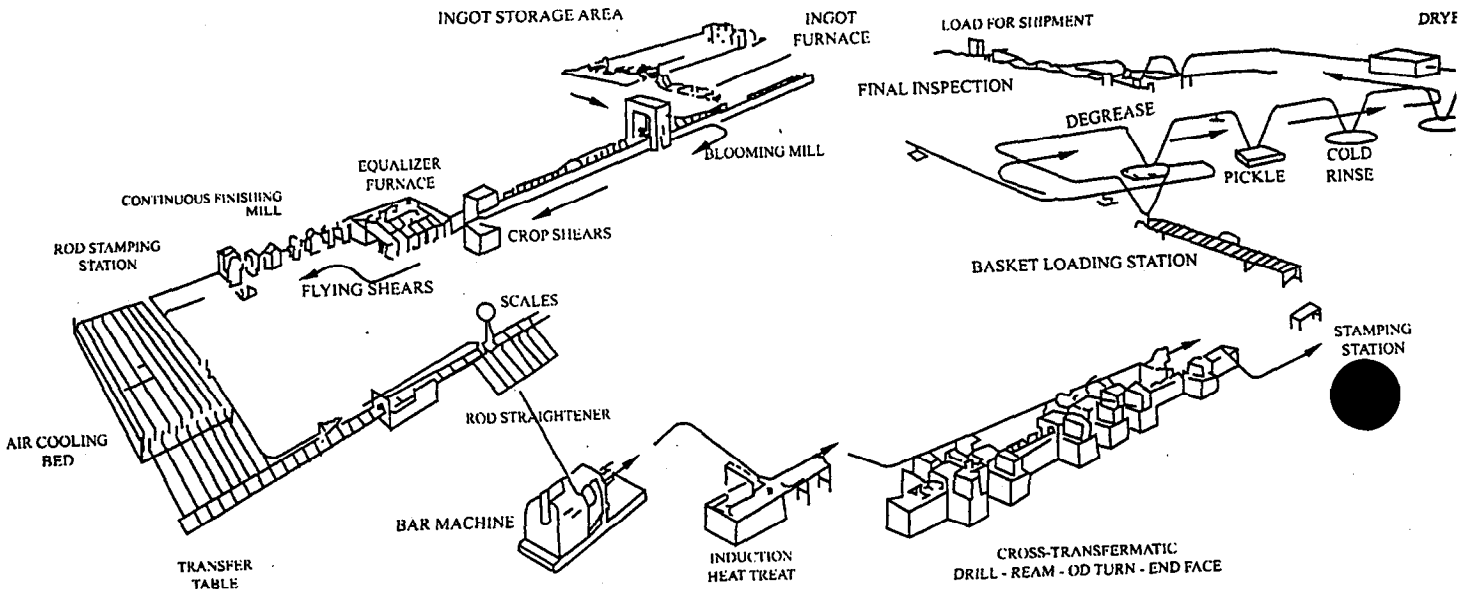


Figure D.1-8 Rolling NAD Machining Process Flow

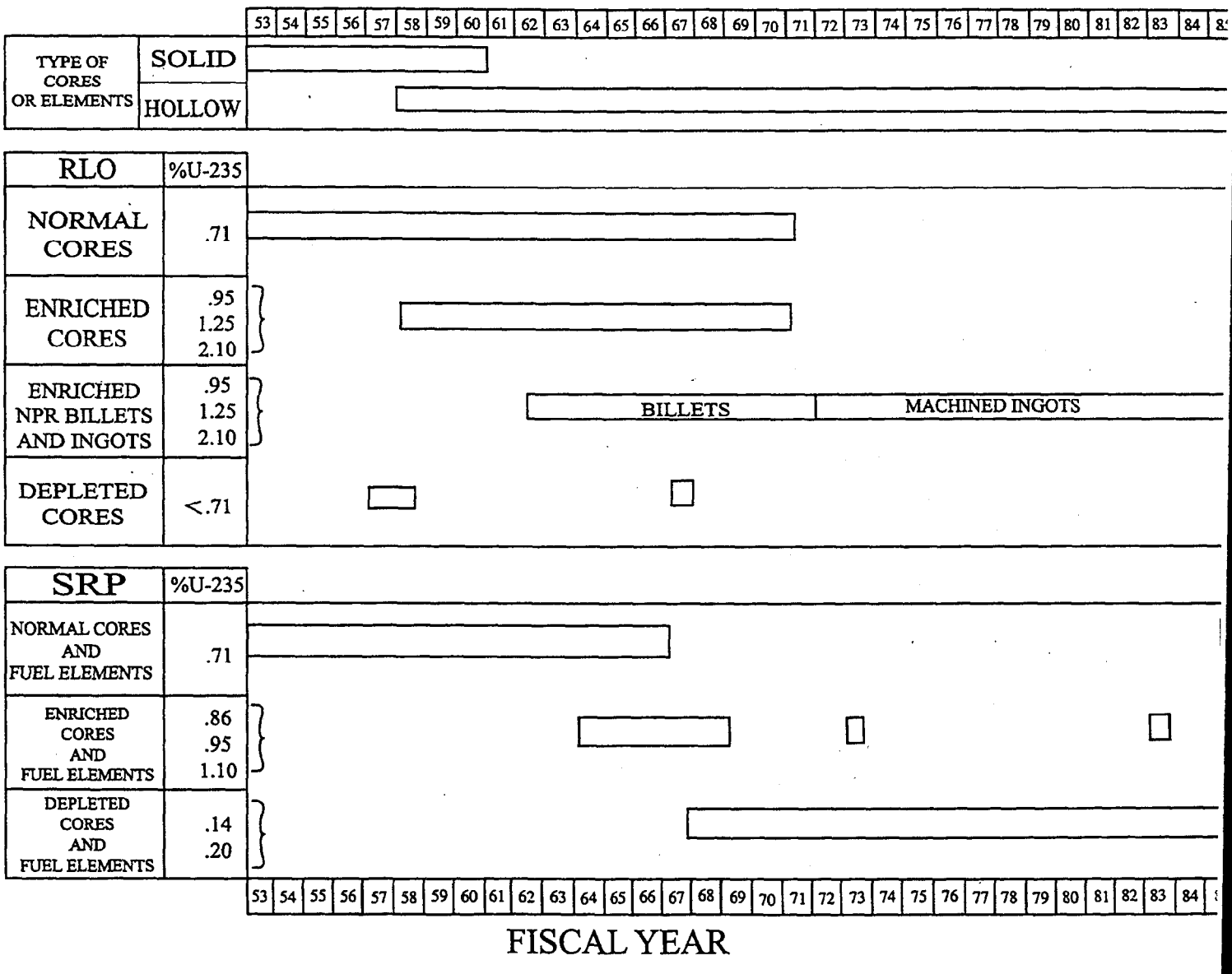


Figure D.1-9 Fiscal Year Normal, Enriched and Depleted Uranium Metal Processing Periods

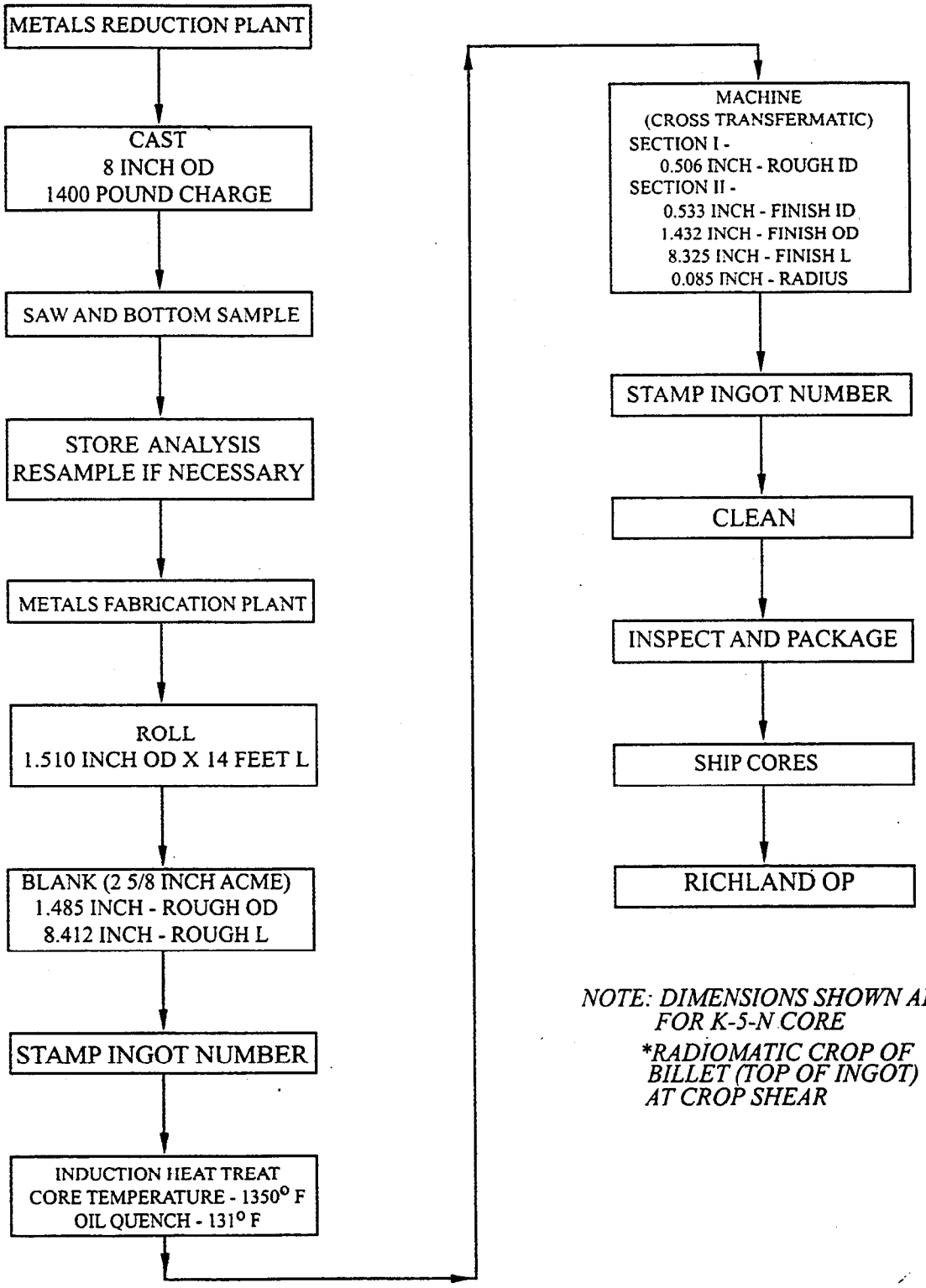


Figure D.1-10 Process Flow for RLO Normal Uranium I&E Cores

TABLE D.1-8

TOTAL PRODUCTION (MTU)
PLANT 6 – RODS

Fiscal Year	Depleted	Normal	Enriched	Total
1952	0	0	0	0
1953	0	1966	0	1966
1954	0	5679	0	5679
1955	0	973	0	9973
1956	0	12470	0	12470
1957	0	15074	0	15074
1958	0	12937	728	13665
1959	0	12887	1146	14033
1960	0	17255	1277	18532
1961	0	13214	2156	15370
1962	0	13518	1912	15430
1963	0	12101	2406	14507
1964	0	8958	2355	11313
1965	0	8925	3385	12310
1966	0	4981	2702	7683
1967	174	5031	2371	7576
1968	5	1895	3129	5029
1969	1	284	3096	3381
1970	4	2801	504	3309
1971	0	959	109	1068
1972	0	0	0	0
1973	0	0	0	0
1974	0	0	0	0
1975	0	0	0	0
1976*	0	0	0	0
1977	0	0	0	0
1978	0	0	0	0
1979	0	0	0	0
1980	0	0	0	0
1981	0	0	0	0
1982	0	0	0	0
1984	0	0	0	0
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	0	0	0	0
1989	0	0	0	0
Totals	184	160908	27276	188368

TABLE D.1-9

CHRONOLOGY – INGOT ROLLING

Fiscal Year	OD Inches	Isotopic Category		
		Depleted	Normal	Enriched
1953	5		X	
1954	7		X	
1958	7			X
1963	8	X		
1963	9	X	X	X
1967	10	X		

TABLE D.1-10

TOTAL PRODUCTION (MTU)
PLANT 6 – CORES AND TARGET ELEMENTS

Fiscal Year	Normal	Enriched	Depleted	Total
1952	0	0	0	0
1953	1608	0	0	1608
1954	3581	0	0	3581
1955	6752	0	0	6752
1956	8086	0	0	8086
1957	8629	0	0	8629
1958	7961	0	0	7961
1959	6660	0	0	6660
1960	8330	0	0	8330
1961	6306	0	0	6306
1962	6906	0	0	6906
1963	7396	0	0	7396
1964	6428	0	0	6429
1965	5665	0	0	5665
1966	3312	1786	0	5098
1967	2983	2639	103	5725
1968	1246	1818	1012	4076
1969	133	1944	1150	3227
1970	1779	326	777	2882
1971	410	0	941	1351
1972	0	0	922	922
1973	0	*	1881	1881
1974	0	0	870	870
1975	0	0	797	797
1976*	0	0	1065	1065
1977	0	0	1110	1110
1978	0	0	1172	1172
1979	0	0	900	900
1980	0	0	999	999
1981	0	0	1127	1127
1982	0	0	1821	1821
1983	0	*	2011	2011
1984	0	0	1924	1924
1985	0	0	1860	1860
1986	0	0	1743	1743
1987	0	0	426	426
1988	0	0	8	8
1989	0	0	0	0
Totals	94171	8513	24619	127303

~~* Mark 15 production incl~~uded in Table 6-4 for these years

TABLE D.1-11

TOTAL PRODUCTION (MTU)
PLANT 9 – CORES AND TARGET ELEMENTS

Fiscal Year	Depleted	Normal	Enriched	NPR Enriched	Total
1952	0	0	0	0	0
1953	0	0	0	0	0
1954	0	0	0	0	0
1955	0	0	0	0	0
1956	0	0	0	0	0
1957	0	0	0	0	0
1958	0	0	417	0	417
1959	0	0	660	0	660
1960	0	0	801	0	801
1961	0	0	1246	0	1246
1962	0	0	1305	0	1305
1963	0	0	1836	0	1836
1964	0	0	2851	0	2851
1965	0	0	3009	0	3009
1966	7	308	1116	1868	3299
1967	145	0	2091	478	2714
1968	1847	5	1404	910	4166
1969	1887	0	0	1093	2980
1970	1277	0	0	675	1952
1971	1550	0	0	132	1682
1972	1301	0	0	537	1838
1973	2666	0	26	375	3067
1974	1295	34	0	892	2221
1975	835	0	0	697	1532
1976*	1711	0	0	284	1995
1977	1778	0	0	296	2074
1978	1487	0	0	445	1932
1979	1132	0	0	427	1559
1980	1525	0	0	263	1788
1981	1613	0	0	601	2214
1982	2890	0	1	675	3566
1983	3005	0	272	1114	4391
1984	2955	0	0	1299	4254
1985	2083	47	0	1299	3429
1986	2859	180	0	1183	4222
1987	227	31	0	451	709
1988	2	0	0	337	339
1989	0	0	0	0	0
Totals	36077	605	17035	16331	70048

Feedstock for the fabrication of fuel cores for Hanford and target elements for Savannah River initially were rods from the Rolling Mill operation. Normal uranium solid type cores were produced for Hanford beginning with the start of operations in 1952. In 1957, Hanford changed to a hollow I&E core, with varying dimensions. Enriched uranium I&E cores also began in 1957. Both normal and enriched uranium a limited quantity of depleted uranium I&E cores were produced for Hanford through 1970. The enriched N-Reactor production stream for Hanford began in Plant 9 during 1960.

The first uranium metal product for Savannah River was a threaded surface, normal uranium, solid core designated Mark I that was manufactured in July 1952. Soon after, the surface was changed from threaded to a smooth finish. In 1957, the manufacture of Mark I cores was replaced by the Mark VII, which continued through 1960. Starting in 1958, ingots were extruded into tubes at Bridgeport Brass Company and at RMI, beginning in 1962, to support production for the Mark V-B tube-in-tube program at Savannah River. Extruded tubes were returned to the FEMP for fabrication into either inner or outer target elements. This practice continued through 1966.

Enriched Mark V-E elements were fabricated for Savannah River from 1963 through 1966, and Mark V-R elements were machined in 1967 and 1968. Mark 30 depleted uranium elements, assaying 0.14 percent U-235, were produced in 1967, and continued until replaced by the production of 0.2 percent U-235 Mark 31 elements. The production of Mark 31 elements continued to the end of the FEMP mission for DOE Defense Programs. In 1973 and again in 1983, quantities of the enriched Mark 15 inner and outer elements were produced for reactor performance demonstration tests at Savannah River.

Beginning in 1973, Savannah River implemented the production of the (0.20 percent U-235) Mark 31 depleted (0.20 percent U-235) production stream, illustrated in Figure D.1-11. All of the process steps for this stream are diagrammed in Figures D.1-12, D.1-13, and D.1-14 for producing cropped ingot castings, heat treated machined ingots, and finished cores, respectively. The process generally began with UF_4 feed from the Paducah inventory and progressed at the FEMP to produce heat treated machined ingots for machined target element cores.

Beginning in 1966, the production demand for rods steadily decreased as the Hanford production reactors were taken out of service. When the last Hanford K-Reactor was shutdown in October 1971, the rolling mill operation was shut down and placed into standby. All machined ingots were heat treated in Plant 6

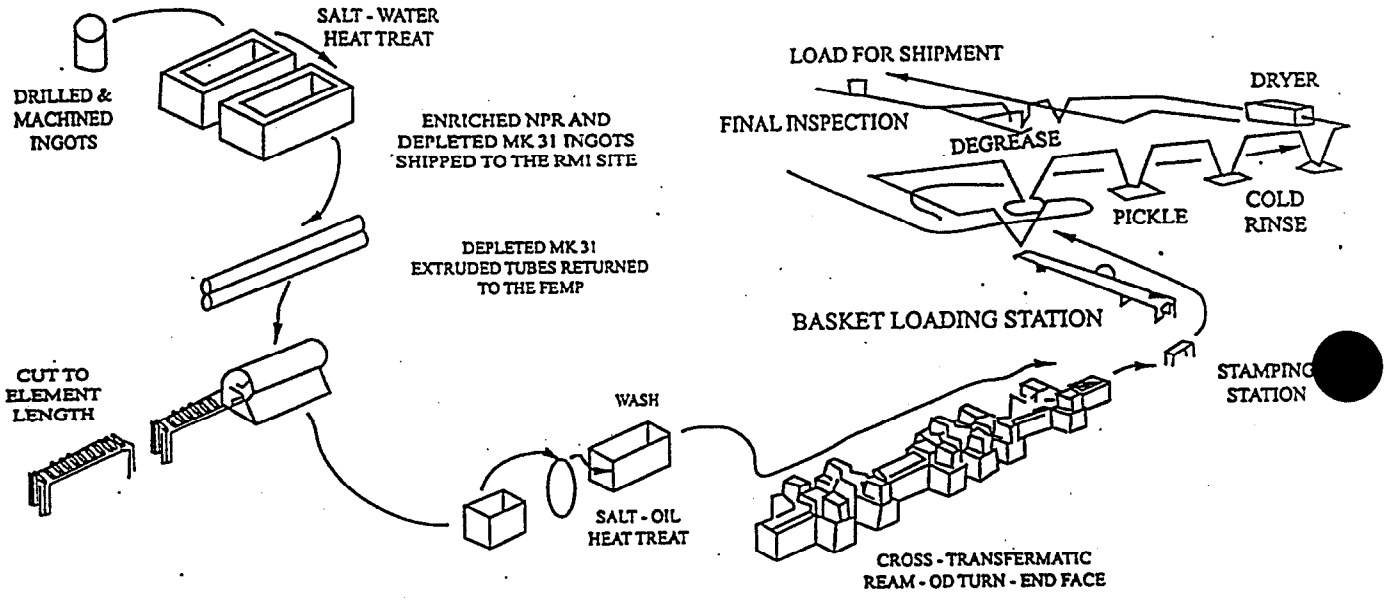


Figure D.1-11 Metal Fabrication Process Flow for Mark 31 Production

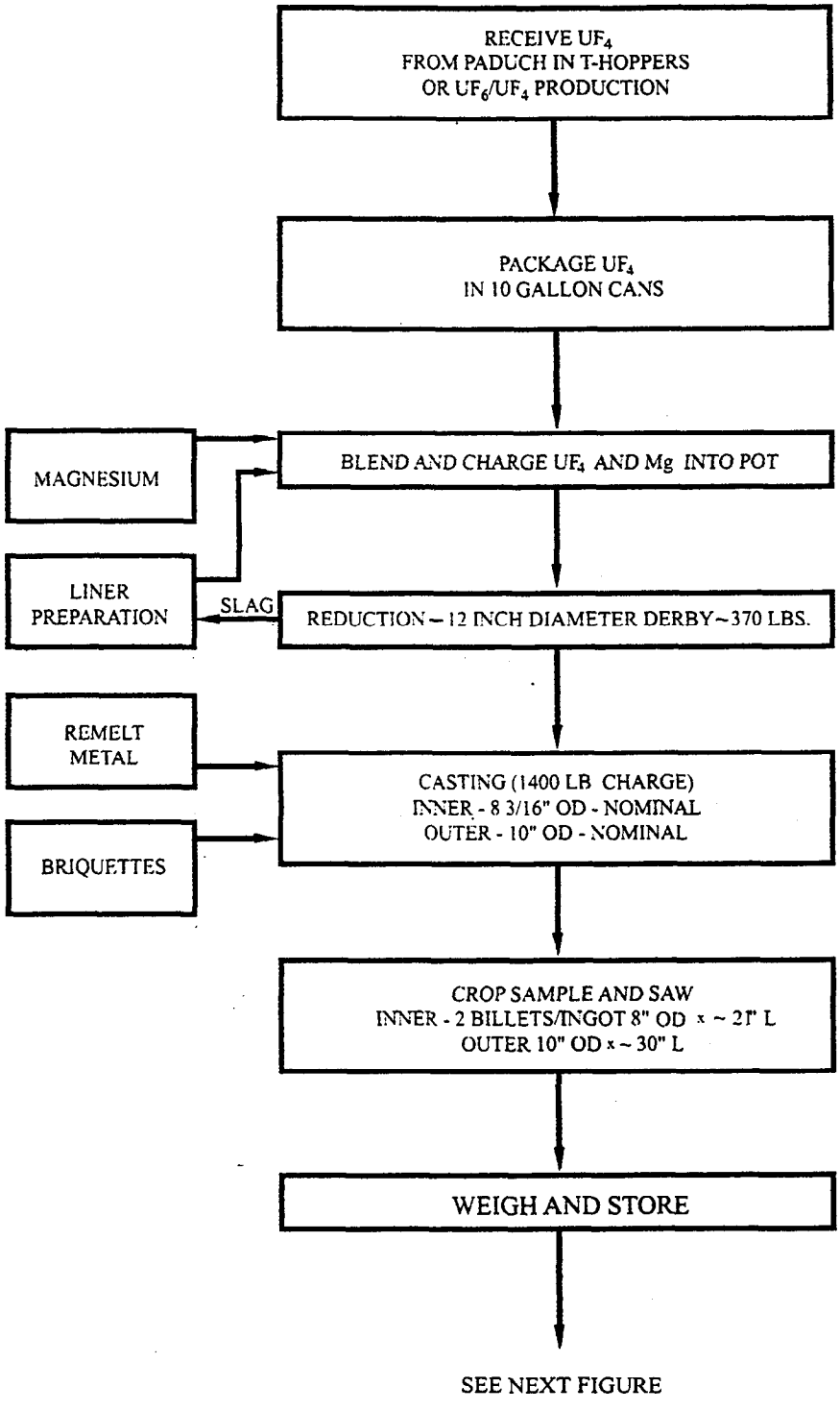


Figure D.1-12 UF_4 Production or Repackaging, Reduction, Casting Process Flow for Mark 30/31 Product

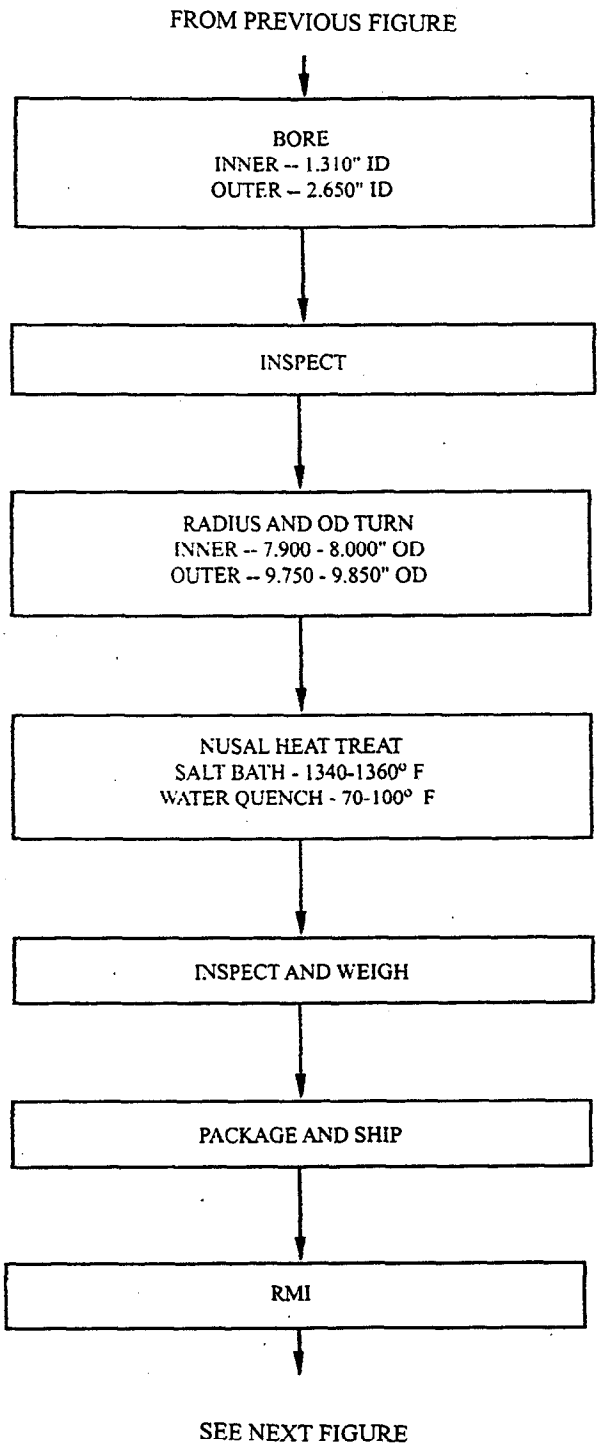


Figure D.1-13 Ingot/Billet Preparation Process Flow for Mark 30/31 Product

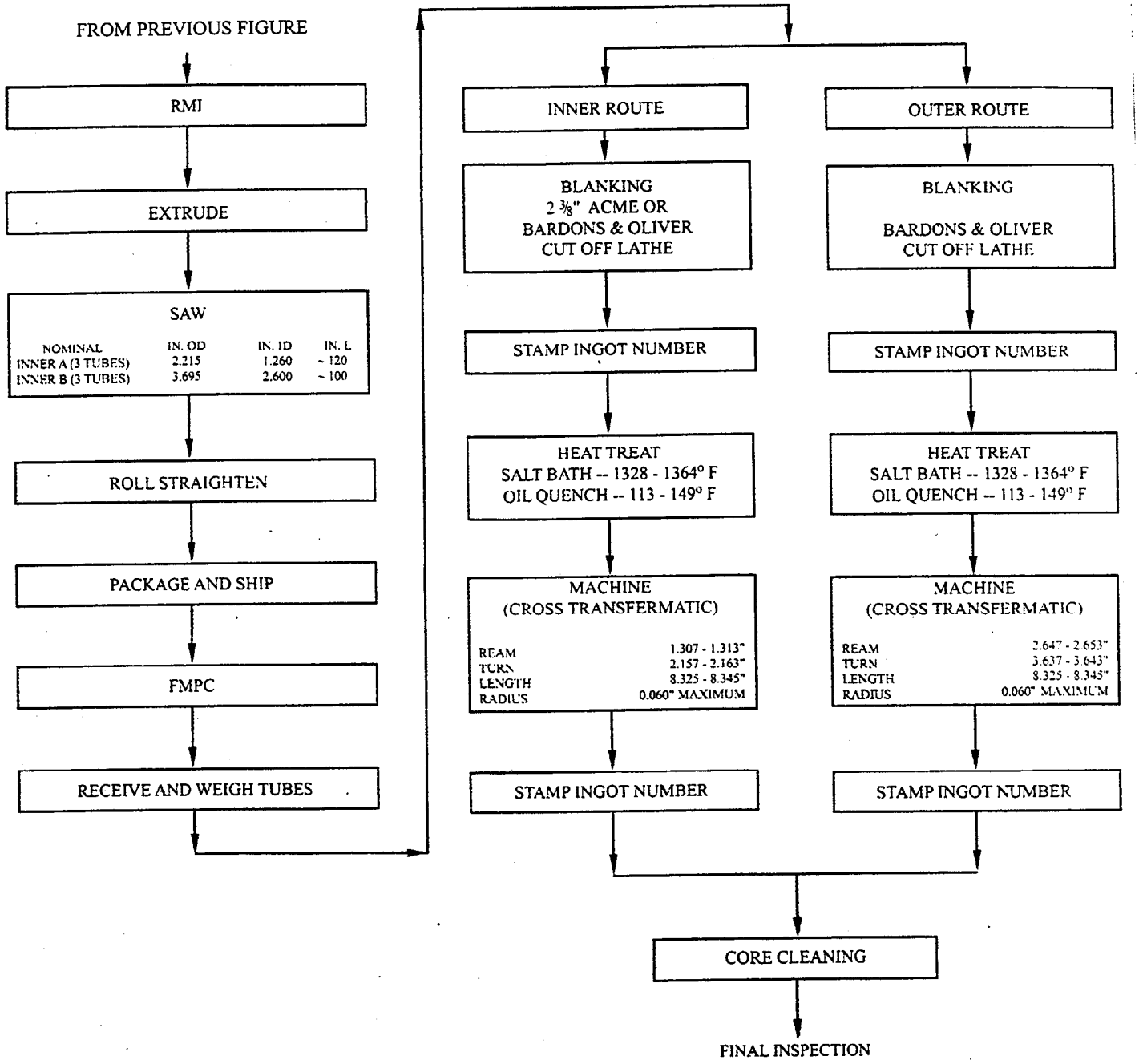


Figure D.1-14 Extrusion and Finish Machining Process Flow for Mark 30/31 Product

before they were shipped to RMI Company for extruding into tubes or forged to billets. Extruded tubes were returned to the Plant 6 for fabrication into finished target element cores for Savannah River. Forged billets were shipped directly to Hanford for co-extrusion into fuel cores.

6.2 PROCESS OPERATIONS

6.2.1 Rolling Mill Operations

Cylindrical cropped ingots having a diameter of 6-8 inches were heat treated prior to the Rolling Mill operation. Equipment originally installed for this operation (see Figure 6-1) consisted of an ingot furnace, blooming mill with reversing rolls, shearing devices, molten salt heat treating furnace, and conveyors. The blooming mill operation produced an oval billet having dimensions of 2 1/4 " x 2 1/2" in cross-section and 37 feet long. After shearing and heat treating, the oval billets advanced to a six-stand finishing mill for machining into rod stock having standard diameters in the range of 1-2". After straightening, the rod stock was transferred to the Machining Area for cutting into sections, center drilling, and surface machining to close tolerances specified for the final cores.

6.2.2 Beta Heat Treating Rolled Rod and Core Blanks

The original beta furnace for heat treating rolled rods for the Hanford production stream was conveniently located in the Rolling Mill Area. Rods were immersed in a bath of molten carbonate salts. After a specified time, the cherry-red rods were removed from the bath and then quenched in water and then allowed to cool in air. Several methods of beta heat treating rods and core blanks to obtain acceptable grain size were employed during the period ending with the shutdown of the Rolling Mill in 1971.

Core blanks were heat treated in the original beta furnace and quenched in either water or oil. The Amsler-Morton furnace was installed in 1962, to molten-salt water-quench normal beta heat treat normal and enriched core blanks for Hanford production. The original beta heat treating equipment was shutdown in 1959, and replaced by the NuSal Furnace for heat treating solid core blanks in a chloride salt bath and water quenching. The NuSal furnace was subsequently modified to heat treat various size ingots and billets.

The Tocco induction heat treat-oil quench unit was installed in 1969, replacing the Amsler-Morton furnace for heat treating Hanford normal and enriched solid core blanks. The Tocco unit was shutdown when the Rolling Mill was placed in standby status in 1971.

Rod stock produced for the Savannah River production was not heat treated in the original equipment. Heat treating of hollow core blanks was performed in a molten bronze bath followed by quenching in a tin bath. This was changed to a salt-bath oil-quench in 1961.

6.2.3 Plant 6 Machining Operations

Equipment installed for these operations (see Figure 6-1) and included six automatic bar machines, four turret lathes, degreaser, and pickling facility. A press for compacting pickled machining chips and turnings into briquettes for remelt recycling was installed during the site expansion project of 1956. After final inspection, these final products were shipped to the user sites. Cores that failed to meet the rigorous quality standards were recycled through remelt operations in Plant 5.

Rods were loaded into an Acme-Gridley machine and cut to a nominal 8-inch length called a core blank for beta heat treating. After heat treating, the core blanks were drilled and reamed in an Acme-Gridley; then, surface machined in a Sundstrand lathe; and finally end-faced and radiused on both ends in a Heald machine. Likewise, tubular elements were produced by cutting extruded tubes from RMI into core blanks, heat treated blanks were reamed on a 6-spindle Acme bar machine; then, surface machined on a lathe; and finally end-faced on a Bore-matic machine.

In 1962, the multi-station Cross Transfermatic Machine was installed and significantly increased the productivity of Hanford I&E core machining operations. Thereafter, all finish machining operations of outer-diameter turning, inner-diameter radiusing, and end-facing of core blanks were performed on the Cross machine. The Bardons and Oliver lathe continued to be used for cutting core blanks from either rod stock or extruded tubes. Finished cores were stamped for identification, loaded into a stainless steel basket, degreased, pickled in mild nitric acid, water-rinsed, and air-dried for final quality inspection for surface defects, dimensional tolerances, and proper grain size.

6.2.4 Plant 9 Machining Operations

Ingot casting, ingot machining, triple beta heat treating, and extrusion operations for supporting the enriched Hanford I&E production stream were developed in 1959. Demonstration casting of hollow ingots weighing 1,500 pounds was conducted using existing Plant 9 equipment in 1959. A plant expansion program was started in 1961, for increasing the limited capacity of equipment used for the production of enriched uranium for the Hanford N-Reactor production stream. Casting furnaces for I&E core production became operational late in 1961, and for the 11-inch and 13-inch diameter ingots for the N-Reactor stream in 1962.

Casting of 13-inch diameter ingots for N-Reactor production improved the workability of uranium metal during the extrusion step at RMI. Billet types produced between 1962 and 1971 for the N-Reactor stream are listed in Table D.1-12.

TABLE D.1-12
TYPES OF NPR BILLETS PRODUCED
(1962 – 1971)

Isotopic Range (% U-235)	Outer	Inner	Type of End	
			Flat	Preshape
0.95 – 1.25	Mark I	Mark I	X	X
0.95 – 1.25	Mark I	Mark I		X
0.95 – 1.25	Mark IV	Mark IV	X	
0.95 – 1.25	Mark IV	Mark IV		X
1.25 – 2.10	Driver			X

Ingots for the N-Reactor stream were changed from hollow to solid castings in 1964, for cost savings. A new LeBlond-Carlstedt Rapid Borer machine was put into operation in 1964. In the same year, Terrapaint coating was applied as an interior coating of ingot molds to improve surface quality. Early in 1966, the alloy additive of aluminum packets was initiated in crucible charges for producing N-Reactor ingots, reducing the ingot heat treat requirement from triple to a single dip in molten salt.

The return of extruded enriched uranium billets from RMI for Plant 9 machining to dimensions for outer and inner billets for the N-Reactor was discontinued in 1971. Thereafter, only machined ingots were sent to RMI for fabrication into billets by the upset forge process. Fabricated billets were shipped directly to Hanford by RMI.

Surface machining, internal boring, and end facing of depleted uranium ingots for the Savannah River production stream was started in 1973. Ingot boring productivity was improved by modifying an excess Monarch lathe for use in conjunction with the LeBlond-Carlstedt Rapid Borer machine.

6.3 SIGNIFICANT EVENTS

During the mid-1950's, dingot metal, a combined derby/ingot, was received from Mallincrodt Chemical Works (MCW) in Saint Louis for rolling into rod stock. Dingots weighing about 3,300 pounds, having dimensions of 17.5 inches diameter and 17 inches length, were received between 1959 and 1966. After scalping and forging to a 7-inch diameter, they were rolled into rod stock for fabrication into cores for Hanford.

In 1962, two new blooming mill pass schedules were implemented so that the Finishing Mill could roll five different rod diameter sizes from 1.219 to 2.031 inches. A further change occurred one year later, when the pass schedule was changed from 21 to 23 for improving the Hanford core yields from 8-inch diameter ingots. Spray quenching of rolled rods was started in 1962, to reduce the rod warping. In 1965, 9-inch diameter ingots were rolled to produce 2.031-inch diameter rod stock.

Two campaigns of short duration were conducted in 1975, to produce 0.75-inch diameter rods in support of the emerging DOD penetrator program. Short-length billets were hand- fed through the Finishing Mill to produce the rods for both the U.S. Air Force and Army. Two more campaigns were conducted during the following year. In one campaign, 24 depleted uranium ingots were rolled to billet size for saw cutting into pieces for remelt, per Army requirements. These pieces were cast into uranium-titanium (U-Ti) alloy ingots, which were then rolled into rods for the XM774 Penetrator program at the Picatinny Arsenal. The second campaign consisted of rolling one high-purity ingot to rod stock for a private sector firm.

7.0 OTHER PILOT PLANT URANIUM OPERATIONS

This unit of the FEMP production complex had a wide range of chemical and metallurgical process equipment for performing demonstration tests or producing smaller quantities of uranium and thorium products. With the emerging thorium programs of the late 1960's, many of the uranium process facilities were adapted for producing purified thorium nitrate, thorium oxalate, thoria gel (hydrated oxide) and metal.

7.1 PRODUCTION HISTORY

The first derby was produced in the Pilot Plant during October 1951. Machining of solid type normal uranium cores was started and continued on an intermittent schedule until the start-up of Plant 6 machining operations in 1953. The Pilot Plant served as a prototype for developing engineering design data for many of the full-scale plant operations. During this period, its facilities were used for training chemical and machine operators.

7.2 PROCESS OPERATIONS

Because of the variety of operations conducted in the Pilot Plant, chemical and metallurgical process operations are described in the following subsections. The Pilot Plant uranium hexafluoride reduction facility is described in Section 3.2 of this Attachment. A 50-curie cobalt-60 source radiographic facility was installed in the Pilot Plant Warehouse in 1965.

7.2.1 Chemical Process and Furnacing Operations

Chemical processing facilities included a solvent extraction system capable of purifying solutions of either uranyl or thorium nitrate at a rate of 1.0 ton per day, using different solvent systems. The standard tri-butyl phosphate (TBP) - Kerosene flowsheet used in Plant 2/3 (See Section 2.2) was used for uranium purification. A new di-amyl, amyl phosphonate (DAAP) solvent system was developed during 1965 for the purification of thorium nitrate feed solutions. A centrifugal (Soxhlet) extraction system was installed in the Pilot Plant during 1973, for the recovery of UF_4 imbedded in paraffin cubes.

The WINLO facility for chemically recovering low enrichment residues was installed early in 1960, and demonstrated that high-grade UF_4 could be routinely produced from a variety of process residues. The significance of this technology was the avoidance of major chemical processing in Plants 2/3, 4, and 8 for producing UF_4 that was suitable for reduction to metal in Plant 5. A full-scale production unit was installed in Plant 8 in 1962, and is described in Section 8.3 of this Attachment.

Limited uranium operations were conducted during thorium production activities during the early 1970's. Higher enriched materials assaying in the range of 2 percent to 10 percent U-235 from the Plant 2/3 evaporator/calciner unit and offsite sources were roasted in the oxidation furnace between 1971 and 1980 to produce U_3O_8 acceptable for shipment to the Portsmouth Gaseous Diffusion Plant as cascade feed.

7.2.2 Metal Production and Fabrication Operations

Metal production and fabrication equipment was used on an intermittent basis for cutting and shaping uranium metal; shot-blasting derbies for removing adhering slag; plasma spraying crucibles and ingot molds; beta heat treating uranium core blanks in a salt bath/oil quench; and centrifuge tube casting. In 1956, enriched uranium metal was produced for several customers. Large ingots weighing 2,300 pounds were vacuum-cast for extrusion tests and methods were developed for the centrifugal casting of solid cores and uranium shot metal during 1958.

7.3 SIGNIFICANT EVENTS

Shipments of surplus unirradiated fuel rods manufactured by Atomics International for the Hallam Reactor began late in 1968. The shipments totalled approximately 30 MTU in the isotopic range of 1.5 percent to 6.5 percent U-235. Rod dimensions were 16 feet in length and a diameter of 0.965 inch. Random lengths of uranium carbide slugs were sodium bonded to the interior of the thin-walled stainless steel clad tube. The recovery process was started early in 1973, and is illustrated in Figure D.1-15. Rods were carefully cut into approximately 1-foot sections using a lathe after removing the end caps that contained all sodium. The cut sections were placed in a water bath to remove the sodium bond by a slow, controlled reaction with water. When the uranium carbide slugs became free of the bond as it dissolved, they were removed from the clad section and placed under water for several days. During this period, the uranium carbide slugs reacted slowly with water to produce uranium oxide sludge. The sludge was steam dried in furnace pots and transferred to the oxidation furnace for calcination to U_3O_8 at 1000 F. After screening and sampling, acceptable product was shipped to the Portsmouth Gaseous Diffusion Plant.

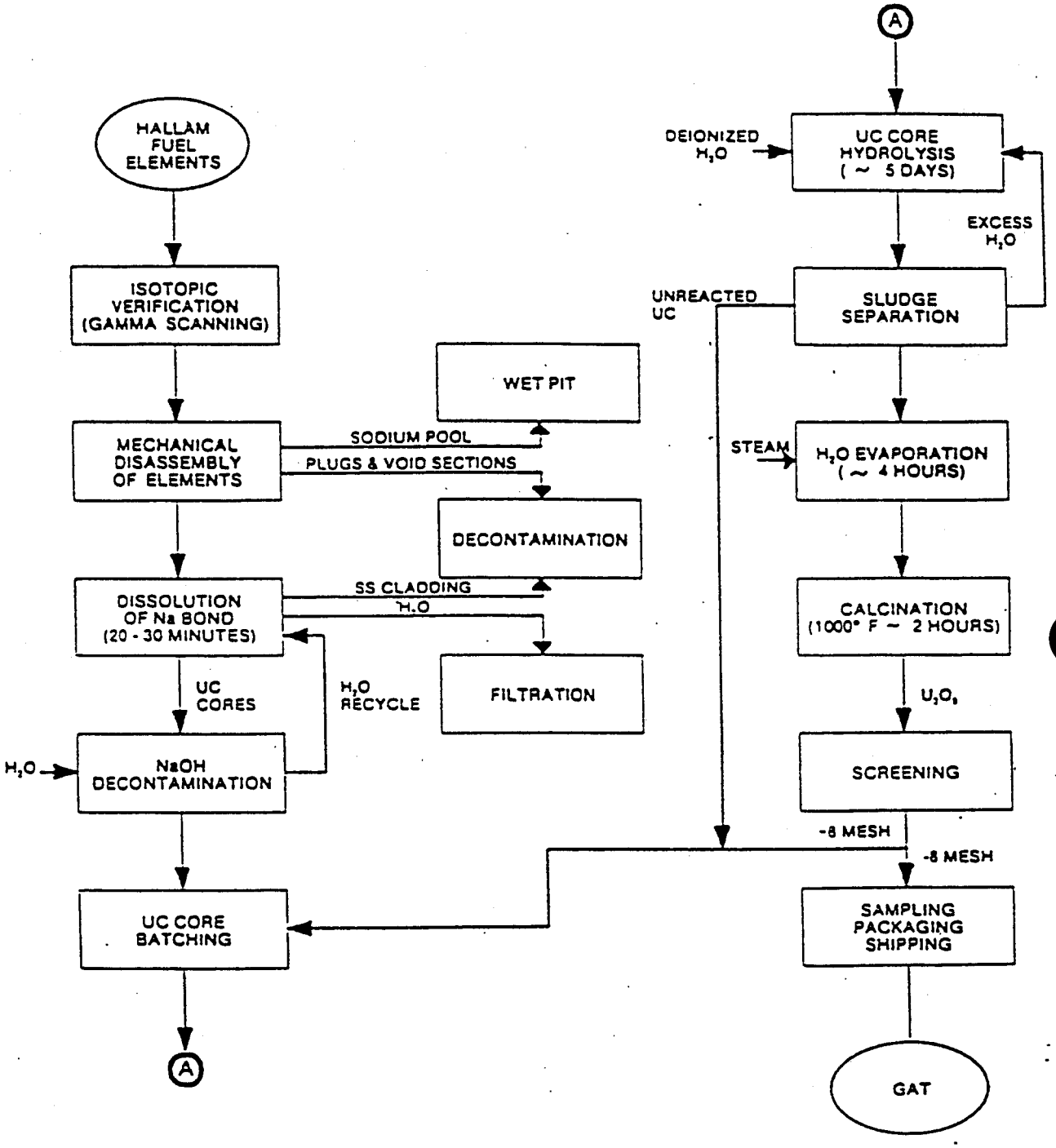


Figure D.1-15 Uranium Recovery From Hallam Fuel Elements

8.0 SCRAP RECOVERY (PLANT 8)

Operations began in Plant 8 late in 1953 for upgrading process residues to quality standards for uranium feed material for Plant 2/3. Process residues were generated by all FEMP production plants and were classified as either high-grade or low-grade according to the type of material and its uranium assay. High-grade materials consisted of residues containing finely divided uranium or magnesium metal, which were oxidized in the feed preparation furnace system. Low-grade residues were chemically processed through a hydrometallurgical system. The origin of residues recycled to Plant 8 for upgrade processing is shown in Figure D.1-16. Process flow diagrams of the feed preparation furnace and hydrometallurgical systems are illustrated in Figures D.1-17 and D.1-18, respectively.

8.1 PRODUCTION HISTORY

Residue recovery operations were designed to handle 1.0 MTU per day of normal uranium residues. The 37-year history of Refinery feed preparation in Plant 8 is summarized in Table D.1-13. During most of the 1950's, the inventory of process residues for recovery remained relatively constant at the 450 MTU level. Inventory trends and production activity during the subsequent decade is shown in Figure D.1-19. The inventory was diverse in nature and was contained in approximately 95,000 steel 55-gallon drums by 1960. A breakdown of this inventory was 65,000 drums of normal, 20,000 drums enriched, 3,000 drums of alloys, and 7,000 drums of miscellaneous materials.

In 1961, the inventory surged to 1,300 MTU and reached a peak level in 1963, when it increased to 2,600 MTU contained in 70,000 drums. At that time, priority was given to operate the plant to reduce the drum inventory rather than to maximize the throughput for preparing Refinery feed. This was done to avoid the cost of re-drumming material contained in deteriorating drums, reduce environmental contamination, and utilize the operations workforce that became available from the suspension of Plant 2/3 operations.

The inventory of enriched low-grade process residues stored in deteriorating drums scheduled for preparing for the SERF (see Section 2.3) operation in Plant 2/3 was eliminated by March 1966. The drum inventory and associated uranium tonnage of all process residues was systematically reduced until both became current with ongoing production operations by mid-1969. From 1969 to 1971, the plant was operated on a limited schedule that processed only current generation process residues. Full-time operations were shutdown at the end of 1971, when the schedule was changed to an intermittent campaign operation through 1980, but then were resumed on a regular basis.

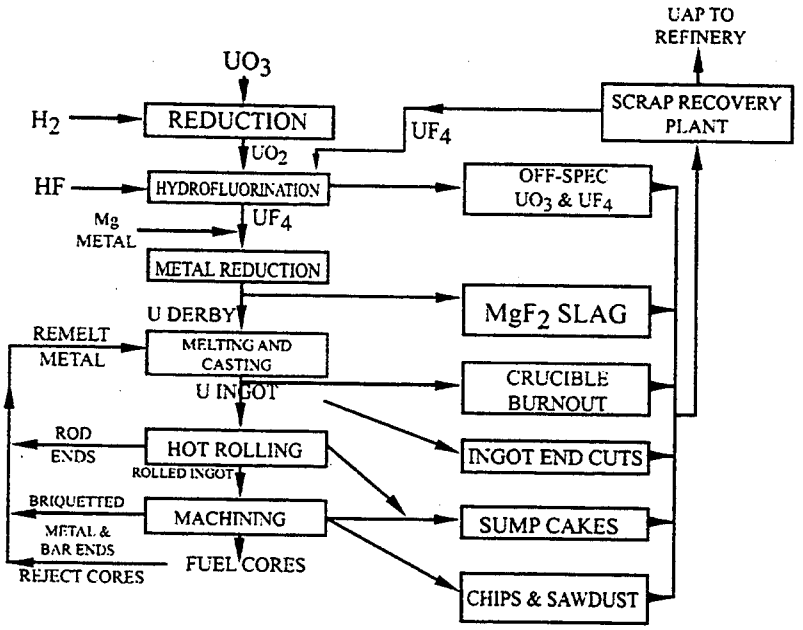


Figure D.1-16 Flowsheet – Origin of Recycle Metal and Residues at FEMP

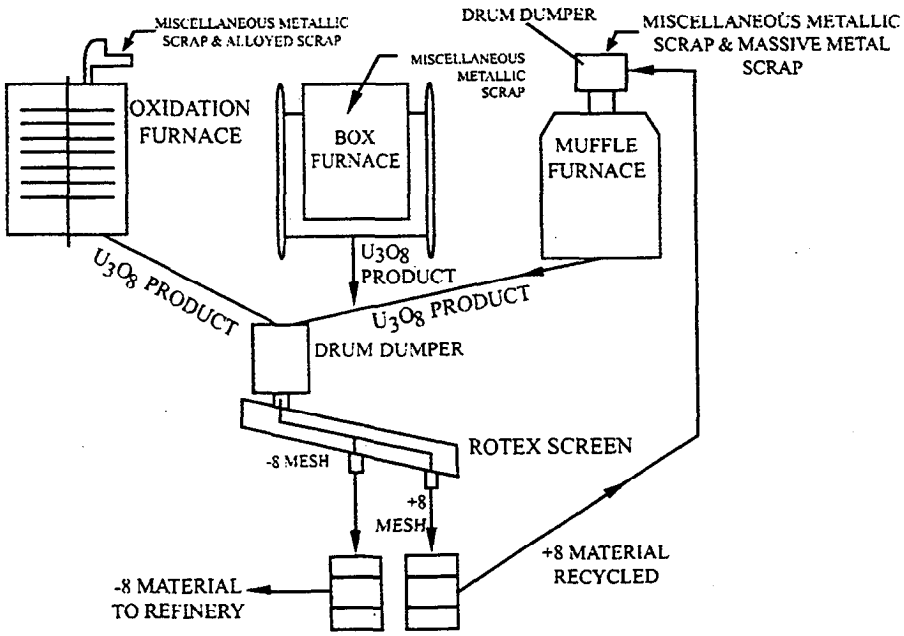


Figure D.1-17 Flowsheet – Feed Preparation From High Grade Scrap

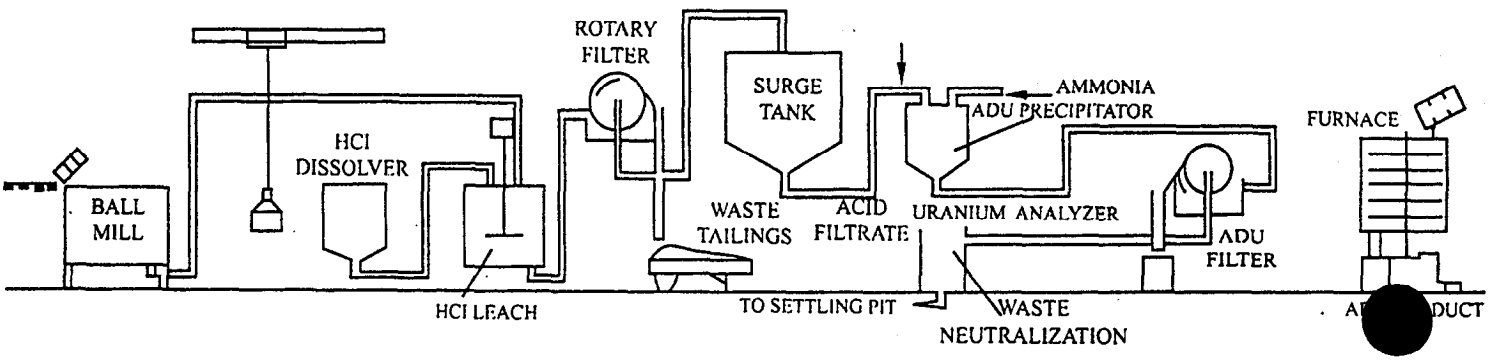


Figure D.1-18 Process Flow Hydrometallurgical System

TABLE D.1-13

TOTAL PRODUCTION (MTU)
PLANT 8 – REFINERY FEED

Fiscal Year	Normal	Enriched	Depleted	Total Uranium	Thorium
1952	0	0	0	0	0
1953	0	0	0	0	0
1954	266	0	0	266	0
1955	1160	0	0	1160	0
1956	1764	0	0	1764	0
1957	1927	0	0	1927	0
1958	2018	0	0	2018	0
1959	2568	0	0	2568	0
1960	3188	0	0	3188	0
1961	2902	0	0	2902	0
1962	2820	0	0	2820	0
1963	2115	542	0	2657	0
1964	2380	1125	0	3505	0
1965	1182	952	0	2134	0
1966	650	967	0	1617	59
1967	855	982	0	1837	0
1968	687	1530	5	2222	0
1969	256	759	21	1036	148
1970	423	204	22	649	100
1971	128	172	7	307	62
1972	7	103	1	111	0
1973	21	45	0	66	0
1974	3	0	0	3	0
1975	11	32	0	43	0
1976	12	39	0	51	0
1977	0	386	0	386	0
1978	0	122	0	122	0
1979	0	184	0	184	0
1980	0	118	0	118	0
1981	0	41	0	41	0
1982	0	237	0	237	0
1983	0	376	0	376	0
1984	0	261	0	261	0
1985	5	143	40	188	0
1986	2	141	33	176	0
1987	0	223	883	1106	0
1988	10	69	181	260	0
1989	0	0	0	0	0
Totals	27360	9753	1193	38306	369

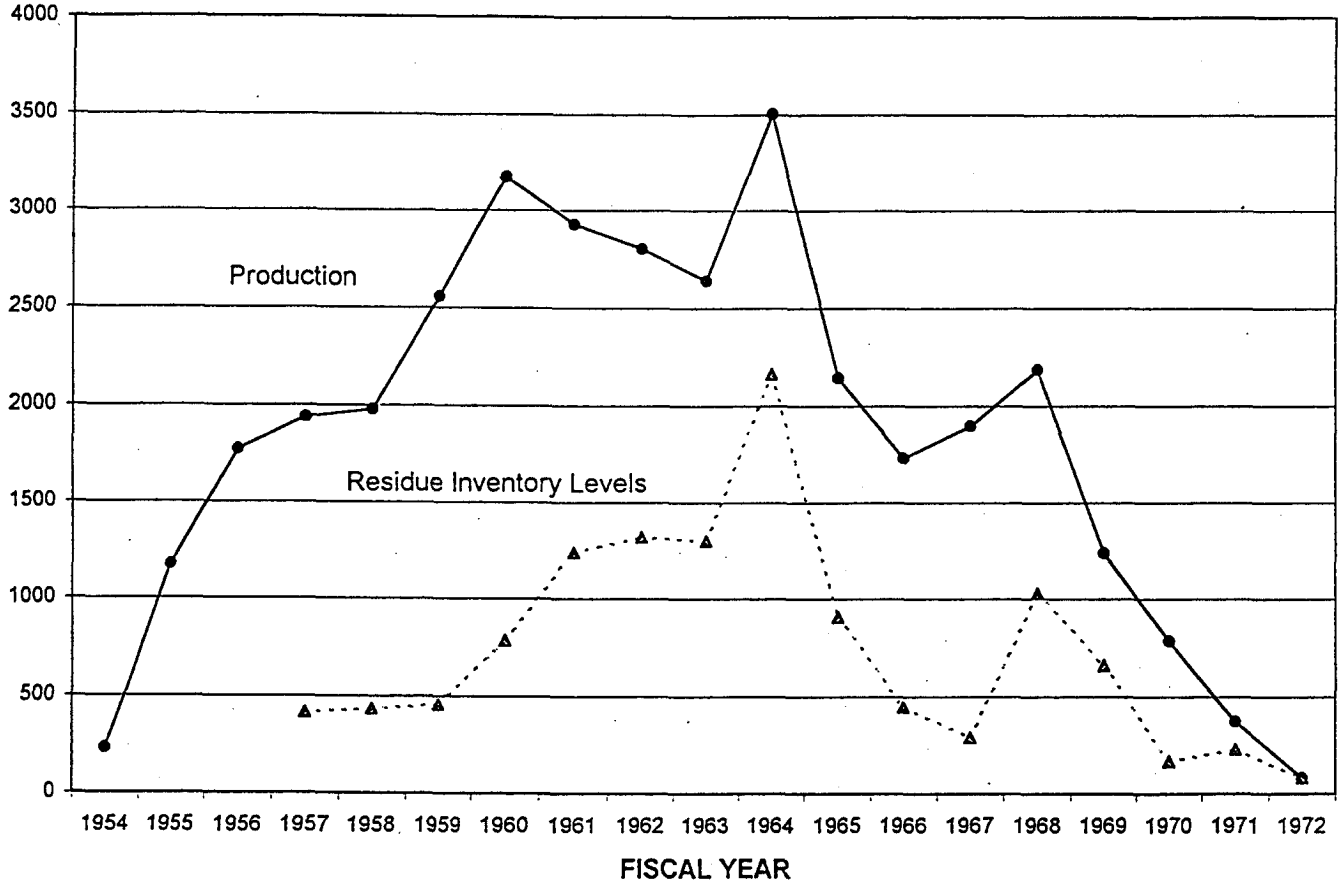


Figure D.1-19 Recovery Plant Trends in Production and Residue Inventory (Beginning of Fiscal Year)

To keep inventories at a minimum, a subcontract was awarded to Vitro rare Earths Corporation to convert 500 tons of ammonium diuranate cake to soda salt and burn 100 tons of uranium-contaminated graphite. Another subcontract was awarded to Union Carbon and Carbide Corporation at the Oak Ridge Y-12 Plant for converting additional quantities of diuranate cake to U_3O_8 ash.

8.2 PROCESS OPERATIONS

The feed preparation furnace system consisting of a series of furnaces specific for the type of material to be roasted. Examples of high-grade residues are uranium chips and turnings that could not be briquetted for remelting; saw chip from metal fabrication operations, and black oxide (U_3O_8). Miscellaneous metallic and alloyed scrap were sent to the Oxidation Furnace; massive metal pieces to the Muffle Furnace; and other miscellaneous metal forms to the Box Furnace. Black oxide furnace product was rotex-screened to separate the coarse (+8) fraction that contained most of the unoxidized metal. This fraction was recycle to the furnaces to complete the oxidation of metal. The screened (-8) fraction was drummed as product.

The hydrometallurgical system to upgrade the overall quality and uranium assay of the material. A primary consideration was the removal of fluoride and chloride constituents that would be corrosive to stainless steel process equipment in Plant 2/3. Some process residues were of sufficient quality for direct dissolution in the hydrochloric acid leach equipment. Residues that were low in free metal or organic content were crushed in a ball mill. The milled product was acid leached in hydrochloric acid and filtered through a rotary vacuum filter. Filtered solids were barren in uranium and were discarded to the waste pits. The acid filtrate was a solution of uranyl chloride, which was precipitated with ammonia in the presence of phosphoric acid to produce uranyl ammonium phosphate (UAP) cake. After filtration, the UAP cake was roasted in one of the furnaces. Phosphorus was needed to chemically complex thorium contained in Canadian ores for removal in the solvent extraction operation in Plant 2/3.

Low-grade residues included MgF_2 slag from metal reduction operations; solidified salts from furnace cleanout and desludging; sump filter cakes, dust collector materials, and incinerator ash. Low-grade metal scrap that was unacceptable for recycling via remelting was furnaced to black oxide (U_3O_8). After screening, the fine material fraction became acceptable feed for Plant 2/3 operations and the coarse material fraction was further oxidized in a furnace.

8.3 SIGNIFICANT EVENTS

With the shutdown of Plant 2/3 in 1962, all products from Plant 8 were shipped to the Weldon Spring Site for conversion to intermediate uranium compounds. This continued until Weldon Spring ceased operations in 1966.

The WINLO facility was installed in 1962, for converting relatively pure, high-grade enriched uranium residues directly to UF_4 via a wet-way precipitation process. Uranium residues were dissolved in hydrochloric acid to produce a solution of uranous chloride (UCl4). This was followed by the addition of dilute (25 percent) hydrofluoric acid byproduct from Plant 4 to precipitate hydrated UF_4. Reducing agents and other additives were used for accelerating the reaction rate and enhancing the yield. The operation was shutdown in 1964 because of the inability to meet specification grade UF_4 and costs associated with dehydrating WINLO product in Plant 4.

Operations were started in mid-1962 for producing feed for the WINLO operation from enriched uranium process residues. Initial throughputs averaged 0.4 MTU per day, but the performance was increased significantly by process and equipment improvements made during the following year. Production continued through April 1964, when sufficient inventories of "300" and "500" enriched WINLO UF_4 had been accumulated.

Plant 8 hydrometallurgical operations were changed in 1967, when the process was changed from UAP to precipitate ammonium diuranate (ADU) cake. This change was implemented because Plant 2/3 was no longer operating on thorium-bearing ores and concentrates. Equally important, the ADU process was a lower cost operation in Plant 8 and a better feed for Plant 2/3 operations than UAP.

In 1974, the Oliver and Eimco filtration systems were reactivated for filtering neutralized raffinate from Plant 2/3. This was necessitated by the inability of Pit 5 to effectively function as a sedimentation basin for raffinate generated from processing ore concentrate feed blends in Plant 2/3. Raffinate from these feed blends contained fine red solids, which settled slowly and compacted poorly in Pit 5. Filter cake was discarded to either Pit 3 or 4 and the neutralized filtrate was sent to the General Sump for discharge to Manhole 175 together with other wastewater streams that met specifications.

In mid-1975, one of many actions taken to restore the operability of Pit 5 was to remove sludge from the pit for transfer to Plant 8 for filtration. The removal was accomplished by pumping sludge using a submersible pump to a nearby high-capacity centrifugal pump that was temporarily located on the berm of the pit. The 4,200-foot transfer line that was routinely used for pumping treated wastewater from the

General Sump Operations to Pit 5 was used to convey the sludge to Plant 8 for filtration. Filter cake was discarded to Pit 3 and filtrate was sent to the General Sump. During a 2-month period, approximately 250,000 gallons of sludge were removed from Pit 5 and filtered in Plant 8. This created a sizable cavity in Pit 5 that allowed the sludge to equalize, and thus, created sufficient capacity that enabled the pit to be returned to limited operations.

Process residues that were recovered and prepared as feed for Plant 2/3 during 1976, were derived or received from Paducah scrap materials. Many of these residues were hand-sorted, screened, and milled before becoming acceptable feed material or suitable for furnacing. Plant 8 facilities were utilized to process wet waste streams to a form suitable for shipment to an offsite disposal facility between 1986 and 1989.

9.0 OTHER PLANT 9 URANIUM OPERATIONS

The Special Products Plant was designed and constructed as a semi-developmental thorium metal production facility because insufficient process information existed to complete a definitive process design.

9.1 PRODUCTION HISTORY

Thorium metal operations commenced late in 1954, even though the two basic processes (thorium fluoride precipitation and induction dezincing/melting) were not able to produce pure thorium metal. Process improvements were eventually implemented that produced quality metal until the demand declined in 1957, when operations were suspended. At that time, the plant equipment was adapted and expanded for the manufacture of special uranium products.

9.2 PROCESS OPERATIONS

Plant 9 metal production and machining operations are described in Sections 5.0 and 6.0, respectively. A program for processing slightly enriched uranium from UF_4 to cores was established in Plant 9 following the replacement of thorium equipment between 1957 and 1958.

9.3 SIGNIFICANT EVENTS

The ZIRNLO decladding process, illustrated in Figure D.1-20, began in Plant 9 during 1963, for chemically removing zirconium and copper jacket materials from unirradiated uranium fuel cores returned as rejects from Hanford's fuel fabrication facility. Clad fuel cores were first immersed in bath of approximately 20 percent hydrofluoric acid to remove the outer zirconium jacket. The chemical reaction ceased when the zirconium jacket was removed, exposing the inner jacket of copper. Then, the copper clad core was immersed in approximately 20 percent nitric acid to remove this jacket by chemical reaction. Care had to exercised so that the chemical reaction did not proceed any further that would have caused the exposed uranium core to react. From 1967 until operations ended, the ZIRNLO processed clad fuel cores ranged from 0.95 percent to 2.1 percent U-235.

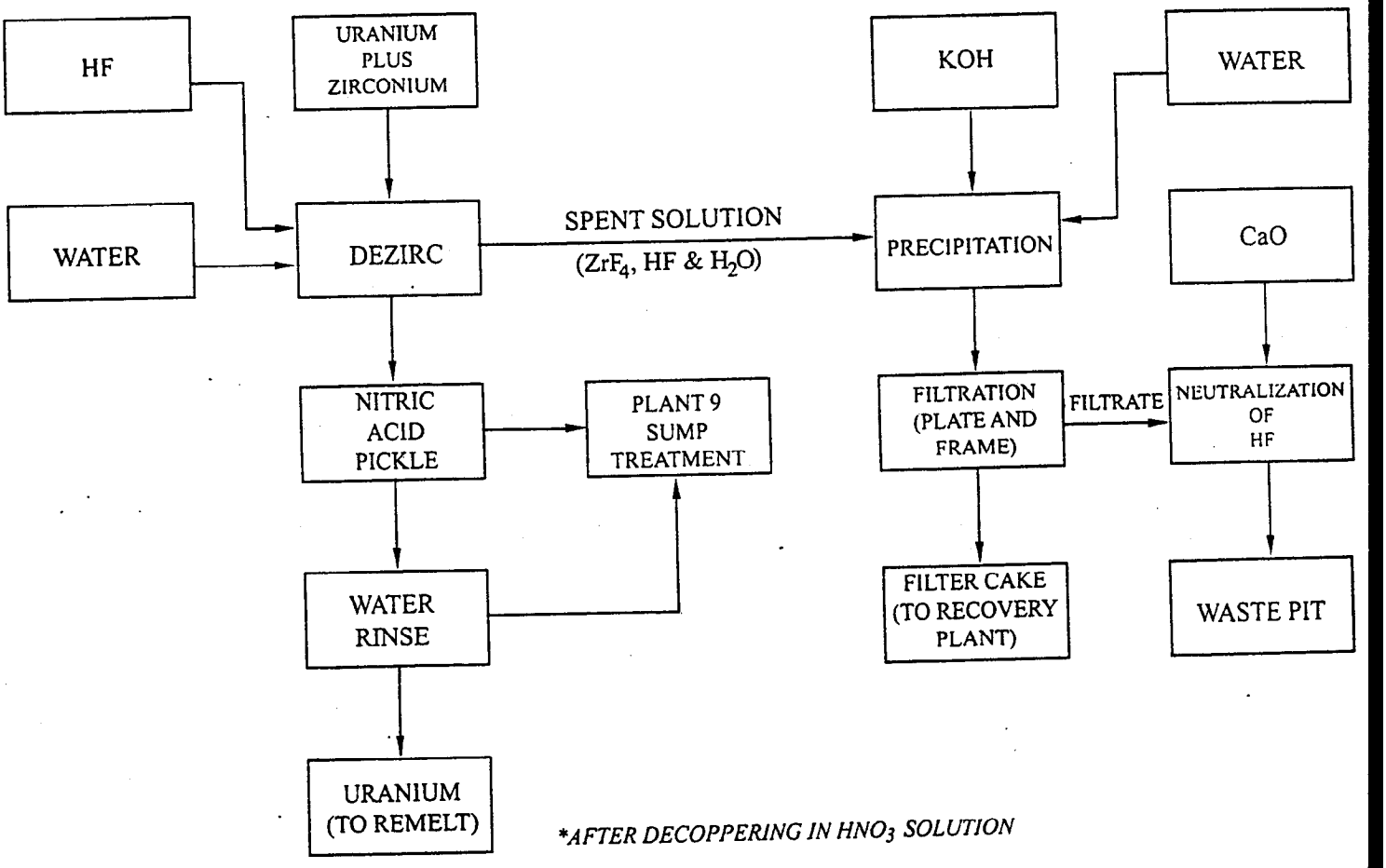


Figure D.1-20 ZIRNLO Process Flow Diagram

10.0 QUALITATIVE ASSESSMENT OF DUST POTENTIAL IN PROCESS OPERATIONS

The FEMP Recycled Uranium Project process team performed a qualitative assessment of potential for airborne dust conditions arising from conducting uranium processing operations at the FEMP. This assessment is based upon the experience and judgment of process knowledge experts who were employed at FEMP dating back to the start of operations in the 1950's. Their range of expertise covers the full spectrum of uranium production operations and the types of materials that were handled and generated by each process. The plant-by-plant assessment delineated in Table D.1-14 below considers only the potential of dust inhalation and not other forms of ingestion or human uptake.

The FEMP Lot Marking and Color Coding System described in Appendix C offers a disciplined approach for assessing every source (SRC) operation that utilized and produced intermediate uranium products/process residues from chemical processes and various forms of uranium metal and scraps from metal production and fabrication operations. The methodology used to access the airborne particulate potential of an operation involved the use of qualitative ratings of "low, medium, and high" to express the potential for dust conditions based upon the nature of the process, level of routine production activity, and operational frequency of the material handling process.

It should be recognized that FEMP production operations that involved handling dry uranium materials were generally equipped with engineered ventilation systems/equipment for controlling airborne particulates. Typical systems/equipment included cyclone separators, bag house dust collectors, wet scrubbers, and portable vacuum systems that were specific to the operation. Operational activities conducted in each plant were governed by an approved set of Manufacturing Standards comprised of Standard Operating Procedures (SOPs) and Manufacturing Specifications. The SOPs were a detailed set of operating instructions and safety requirements for conducting each step of the process. Safety requirements typically specified the use of dust-type respirators for personnel protection when dusty conditions were expected to occur. Additional emphasis was placed upon maintaining good housekeeping practices and the immediate cleanup of spilled materials. The Manufacturing Specifications defined requirements for nuclear criticality safety, materials control and accountability, and performance specifications for raw materials, processes, and products.

Qualitative "high" potential ratings were assessed for high tonnage operations that were susceptible to occasional off-normal events. Examples of such events in the chemical plants were digestion area tank fuming and foam over and denitration pot eruptions in Plant 2/3; failure of the hydrofluorination banks in Plant 4; and temperature excursions in Plant 8 furnace operations. The major occurrences in the metals

plants were blowout of metal reduction charges in Rockwell Furnaces and self-pour castings in Plant 5 and 9. In these off-normal situations, the installed ventilation systems were ineffective at adequately controlling dust emissions.

Another consideration for high potential exposure was the failure of the dust collector bags, blow ring devices or when replacing dust collector bags. In these instances, the process was typically shut down if an alternate online dust collector could not be provided. Operational practices included requirements for the production process operators to clean uranium materials from the dust collector unit and bags before releasing the equipment to Maintenance for bag replacement and return to service. This practice of equipment clean out prior to maintenance/repair was generally followed throughout all FEMP production operations. Accordingly, the systems/equipment with high potential ratings consider both operating and maintenance personnel.

Qualitative "low" potential ratings were assessed for low tonnage operations that were conducted intermittently; did not involve handling appreciable amounts of dry materials; and were highly reliable generally and not susceptible to off-normal events. As expected, qualitative "medium" potential ratings were assessed for operations whose performances were not clearly "high" or "low". Operations such as equipment clean out prior to maintenance/repair were more likely to encounter higher dust levels.

An overall qualitative assessment of dust potential is provided in summary (Table D.1-14) and in detail (Table D.1-15).

Table D.1-14

Qualitative Assessment of Potential for Airborne Recycled Uranium Dusts (Summary)

Potential	Plant	Area	Materials
High	5	Metal Reduction, Casting	UF_4, MgF_2, U, U_3O_8, Residues
	8	Feed Preparation Furnaces	U_3O_8, U, Residues
	4	Banks 7-9, Packaging Stations	UO_3, UO_2, UF_4
Medium	2/3	Digestion, Denitration	Prepared Feed, U_3O_8, MgF_2
	9	Reduction, Casting	UF_4, MgF_2, U, U_3O_8, Residues
	Pilot	Hex Reduction, Metal Operations	UF_4, MgF_2, U, U_3O_8, Residues
Low	6	Rolling Mill	U_3O_8, Metal Scraps Residues
	1	Milling	MgF_2, UO_2, U_3O_8, Residues

Table D.1-15
Qualitative Assessment of Potential for Airborne Recycled Uranium Dusts

Plant	SRC	Operation	Material	Potential
1	100	Plant 1 General	MgF_2, UO_2, U_3O_8, Residues*	Low
	101	Plant 1 Maintenance	MgF_2, UO_2, U_3O_8, Residues*	Low
	102	Maintenance Shop (RCRA)	MgF_2, UO_2, U_3O_8, Residues*	Low
	103	Oil Storage Area	RCRA, TSCA	Low
	105	Construction Waste	Contaminated Rubble	Low
	107	Source Unknown	Miscellaneous Materials	Low
	110	Plant 1 Milling - General	MgF_2, U_3O_8, Residues	High
	111	Drum Dumper	MgF_2, U_3O_8, Residues	High
	112	Titan Mill	MgF_2, U_3O_8, Residues	High
	113	Dust Collector #64	MgF_2, U_3O_8, Residues	High
	114	Dust Collector #76	MgF_2, U_3O_8, Residues	High
	115	Three Phase Gallagher Sampler	MgF_2, U_3O_8, Residues	Low
	116	Hopper or Drum Filling Station	MgF_2, U_3O_8, Residues	Medium
	117	Hoffman Vacuum	MgF_2, U_3O_8, Residues	High
	118	Safe Geometry Digestion	UO_2, U_3O_8	Low
	119	Fitz Mill	UO_2	High
	130	Plant 1 Drum Reconditioning	Residue Scaling	Low
	131	Shot Screen	Residue Scaling	Low
	132	Wheelabrator Shot Blaster Unit	Residue Scaling	Low
	133	Drum Roller	Residue Scaling	Low
	134	Pangborn Dust Collector	Residues	High
	135	Drum Painting Booth	None	Low
	136	Drum Dryer	None	Low
	137	Drum Baler	Residue Scaling	Low
	140	Plant 1 Sampling	Wet and Dry U Residues	Low
	141	Small Sheathed Auger	Dry U Residues	Low
	142	Wheelabrator Dust Collector	Dry U Residues	High
	143	Large Sheathed Auger	Dry U Residues	Low
	144	Pipe Sampler	Wet U Residues	Low
	145	Sly Dust Collector	Dry U Residues	High
	150	Copper Shredder	Residue Scaling	Low
	151	Copper Pile	Residue Scaling	Low

*Also, uranium ores and ore concentrates during the through1961.

Plant	SRC	Operation	Material	Potential
2/3	200	Plant 2/3 General	Prepared Feed, MgF_2, U_3O_8	Low
	201	Plant 2/3 Maintainence	Prepared Feed, MgF_2, U_3O_8	Low
	202	Maintenance Shop (RCRA)	Prepared Feed, MgF_2, U_3O_8	Low
	203	Oil Storage Area	RCRA, TSCA	Low
	210	Plant 2 Digestion*	Prepared Feed, MgF_2, U_3O_8	High
	211	South Side Digesters*	Prepared Feed, MgF_2, U_3O_8	High
	212	North Side Digesters*	Prepared Feed, MgF_2, U_3O_8	High
	213	Turner-Hawes Dust Collector	Prepared Feed, MgF_2, U_3O_8	High
	214	Day-Hoffman Dust Collector	Prepared Feed, MgF_2, U_3O_8	High
	215	Sly Dust Collector	Prepared Feed, MgF_2, U_3O_8	High
	216	Sparkler Filter	Prepared Feed, U_3O_8	Low
	220	Metal Dissolver**	U, U_3O_8	High

Table D.1-15
Qualitative Assessment of Potential for Airborne Recycled Uranium Dusts (continued)

Plant	SRC	Operation	Material	Potential
2/3				
	221	Oliver Filter	Prepared Feed, U_3O_8	Low
	222	Metal Dissolver Grate	U	Low
	225	Extraction	UNH Solution, Organic	Low
	226	South Side Extraction Line	UNH Solution, Organic	Low
	227	North Side Extraction Line	UNH Solution, Organic	Low
	228	Mixer-Settler System	UNH Solution, Organic	High
	230	Solvent Treatment	Organic, Na_2CO_3 Solution	Low
	235	Hot Raffinate Bldg (Slag Leach)	UNH Solution, MgF_2	Low
	236	Filters	UNH Solution, MgF_2	Low
	240	Trash Baler, Kelly Incinerator	Contaminated Trash	Low
	245	Refinery Sump System	UNH Solution, MgU_2O_7	Low
	246	Dorr Thickener	MgU_2O_7	Low
	250	Raffinate Evaporator	UNH Solution	Low
	255	Absorbers	HNO_3	Low
	256	Plant Column Absorbers	HNO_3	Low
	260	Denitration	UNH Solution, UO_3	High
	261	Denitration Scrubbers	UNH Solution, UO_3	Low
	262	South Side Packaging Station	UO_3	High
	263	North Side Packaging Station	UO_3	High
	267	Safe Geometry Evap/Calc	UNH Solution, U_3O_8	Low
	268	Pullman Vacmobile	Prepared Feed, U_3O_8, MgF_2	Low
	270	Drum Digestion	Prepared Feed, U_3O_8, UNH	High
	271	Cartridge Filter	Prepared Feed, U_3O_8, UNH	Low
	272	Plate and Frame Filter	Prepared Feed, U_3O_8, UNH	High

*Includes North and South Drum Dumping Stations
**Includes West Metal Dissolver Tank

Plant	SRC	Operation	Material	Potential
4	400	Plant 4 General	UO_3, UO_2, U_3O_8, UF_4	Low
	401	Plant 4 Maintenance	UO_3, UO_2, U_3O_8, UF_4	Low
	402	Maintenance Shop (RCRA)	UO_3, UO_2, U_3O_8, UF_4	Low
	403	Oil Storage Area	RCRA, TSCA	Low
	407	Bank 7	UO_3, UO_2, UF_4	High
	408	Bank 8	UO_3, UO_2, U_3O_8, UF_4	High
	409	Bank 9	UO_3, UO_2, UF_4	High
	410	Tank Farm	Dilute HF	Low
	411	Sampling	UO_3, UO_2, U_3O_8, UF_4	Low
	420	Dust Collectors - General	UO_3, UO_2, U_3O_8, UF_4	High
	440	Packaging Station - General	UO_3, UO_2, U_3O_8, UF_4	High
	441	East Packaging Station	UF_4	High
	442	West Packaging Station	UF_4	High
	443	SW Packaging Station	UF_4	High

Table D.1-15
Qualitative Assessment of Potential for Airborne Recycled Uranium Dusts (continued)

Plant	SRC	Operation	Material	Potential
5	500	Plant 5 General	UF_4, MgF_2, U, Residues	Low
	501	Maintenance	UF_4, MgF_2, U, Residues	Low
	502	Maintenance Shop (RCRA)	UF_4, MgF_2, U, Residues	Low
	503	Oil Storage Area	RCRA, TSCA	Low
	504	Sampling	UF_4, MgF_2, U, Residues	Low
	509	Drum Storage Pad	UF_4, MgF_2, U, Residues	Low
	510	Metal Reduction	UF_4, MgF_2, U	High
	511	Blenders	UF_4	Low
	512	Filling and Capping Dust Collectors	UF_4, MgF_2	High
	513	Jolter Area Dust Collectors	MgF_2, U_3O_8	High
	514	Bomb Filling Station	UF_4, MgF_2	High
	515	Cap and Lid Station	UF_4, MgF_2	High
	516	Rockwell Furnaces	UF_4, MgF_2 U	High
	517	Cooling Tanks	Contaminated Water	Low
	518	Breakout Stations	U, MgF_2	High
	519	East Breakout Area Dust Collectors	MgF_2	High
	520	West Breakout Area Dust Collectors	MgF_2,	High
	521	Derby Quench	U, U_3O_8, Contaminated Water	Low
	522	Slag Conveyor Pit	U, Mg F_2	High
	523	Pot Reaming Station	U, Mg F_2	Low
	524	Dust Collector	U_3O_8, MgF_2, Residues	High
	530	Casting Area	U, U_3O_8, Residues	High
	531	Remelt Furnaces	U, U_3O_8, Residues	High
	532	Separation Booth	U, U_3O_8, Residues	High
	533	Remelt Dust Collector	U_3O_8, Residues	High
	534	Crucible Burnout	U, U_3O_8, Residues	High
	535	Crucible Burnout Dust Collector	U, U_3O_8, Residues	High
	536	Sly Dust Collector #100	U_3O_8, Residues	High
	538	Hilco Oil Filter	Contaminated Oil	Low
	539	Burnout and Mold Tanks	U, U_3O_8, Residues	High
	540	Graphite Breakup Stations	U, U_3O_8, Residues	Low
	545	Sump Treatment Area	Wet Residues	Low
	550	Saw Area	U, U_3O_8	Medium
	551	Hack Saw	U, U_3O_8	Medium
	552	North Circular Saw	U, U_3O_8	Medium
	553	East Circular Saw	U, U_3O_8	Medium
	554	West Circular Saw	U, U_3O_8	Medium
	560	East Slag Plant	U, Mg F_2	High
	561	Crusher	U, Mg F_2	High
	562	Coarse Separator	U, Mg F_2	High
	563	Fine Separator	U, Mg F_2	High
	564	Bin 4 -20 Mesh MgF2	U, Mg F_2	High
	565	Bin 3 +20 Mesh MgF2	U, Mg F_2	Low
	566	Bins 5,6,7,8 MgF2	U, Mg F_2	High
	570	West Slag Plant	Did Not Operate	
	571	Crusher	Did Not Operate	
	572	Coarse Separator	Did Not Operate	
	573	Fine Separator	Did Not Operate	

Table D.1-15
Qualitative Assessment of Potential for Airborne Recycled Uranium Dusts (continued)

Plant	SRC	Operation	Material	Potential
5				
	574	-20 Mesh MgF2	Did Not Operate	
	575	+20 Mesh MgF2	Did Not Operate	

Plant	SRC	Operation	Material	Potential
6	600	Plant 6 General	U_3O_8, Scraps, Residues	Low
	601	Maintenance	U_3O_8, Scraps, Residues	Low
	602	Maintenance Shop (RCRA)	U_3O_8, Scraps, Residues	Low
	603	Oil Storage Area	RCRA, TSCA	Low
	605	Sampling	U_3O_8, Scraps, Residues	Low
	610	Rolling	U_3O_8, Scraps, Residues	Medium
	611	Ingot Furnace	U_3O_8, Residues	Medium
	612	Blooming Mill	U_3O_8, Scraps, Residues	Medium
	613	Crop or Gag Shear	U_3O_8, Scraps, Residues	Medium
	614	Equalizer Furnace	U_3O_8, Scraps, Residues	Medium
	615	Continuous Mill	U_3O_8	Medium
	616	Flying Shear	U_3O_8	Medium
	617	Cooling Beds	U_3O_8	Medium
	618	Straightener	U_3O_8	Medium
	619	Inspection - Rod Area	U_3O_8	Medium
	620	Machining	U_3O_8, Scraps	Medium
	621	Blanking Acmes	U_3O_8, Scraps	Medium
	622	Cross Transfermatic	U_3O_8, Scraps	Medium
	623	Centerless Grinders	U_3O_8, Scraps	Medium
	624	Drlling Acmes	U_3O_8, Scraps	Medium
	625	Sundstrand Lathes	U_3O_8, Scraps	Medium
	626	Heald Borematics	U_3O_8, Scraps	Medium
	627	Turret Lathes	U_3O_8, Scraps	Medium
	632	CNC Lathe	U_3O_8, Scraps	Low
	640	Heat Treating	U_3O_8, Scraps, Residues	Medium
	642	Salt Oil	U_3O_8, Scraps, Residues	Medium
	643	Nu-Sal	U_3O_8, Scraps, Residues	Medium
	645	Briquetting	U_3O_8, Scraps, Residues	Medium
	646	Chip Crusher	U_3O_8, Scraps, Residues	High
	647	Chip Pickling Tanks	U_3O_8, UNH, Scraps	Low
	648	Chip Briquetting Press	U_3O_8	Medium
	650	Dust Collectors	U_3O_8, Scraps, Residues	High
	652	Turner Hawes Dust Collector	U_3O_8, Scraps, Residues	High
	660	Degreasing and Pickling	U_3O_8, UNH Solution	Low*
	661	Derby Pickling	U_3O_8, UNH Solution	High
	662	Core Pickling	U_3O_8, UNH Solution	Low
	663	Remelt Metal Pickling	U_3O_8, UNH Solution	Medium
	665	Inspection	U	Low
	670	Hopper Repackaging Station	U_3O_8, Scraps, Residues	Low

*Low in U, but high in degreasing solvent vapors.

Table D.1-15
Qualitative Assessment of Potential for Airborne Recycled Uranium Dusts (continued)

Plant	SRC	Operation	Material	Potential
8	800	Plant 8 General	U, U_3O_8, ADU, Residues	Low
	801	Maintenance	U, U_3O_8, ADU, Residues	Low
	802	Maintenance Shop (RCRA)	U, U_3O_8, ADU, Residues	Low
	803	Oil Storage Area	RCRA, TSCA	Low
	804	Super Compactor	Contaminated Trash	Low
	805	Drum Washer	Residue Scaling	High
	806	Drum Reconditioning	Did Not operate	
	810	Wet-Chemical System	Residues, ADU	High
	811	Primary Calciner	Residues, ADU	High
	812	Plant 8 Milling	U_3O_8	High
	814	Digestion	Residues	High
	815	EIMCO Filters	Residues	Low
	816	Precipitation	Residues, ADU	Low
	817	Oliver Filter	Residues, ADU	Low
	818	Calcination	ADU, U_3O_8	Medium
	819	Leach Tank	U, U_3O_8, ADU, Residues	Low
	820	Oxidation System	ADU, U_3O_8, U , Residues	High
	821	Crusher	U_3O_8, U, Residues	High
	822	Rotex Screening	U_3O_8, U, Residues	High
	823	Muffle Furnace	U_3O_8, U, Residues	High
	824	Box Furnace	U_3O_8, U, Residues	High
	825	Oxidation #1	U_3O_8, U, Residues	High
	826	Rotary Kiln - Old Unit	U, U_3O_8, ADU, Residues	High
	827	Oxidation #2	U_3O_8, U, Residues	High
	828	Plant 8 Dust Collectors	U_3O_8, U, Residues	High
	830	Rotary Kiln - New Unit	Did Not Operate	
	845	Hydraulic Separator	Contaminated Water	Low
	852	Blending and Screening	U_3O_8, U, Residues	High
	853	Oil Decantation	Contaminated Oil	Low
	854	Dust Collector and Filter Bag Washing	U_3O_8, U, Residues	High
	855	Air Separator	U_3O_8, U, Residues	High
	856	Hand Sorting	Residues, U_3O_8, U	High

Plant	SRC	Operation	Material	Potential
9	900	Plant 9 General	UF_4, MgF_2, U, U_3O_8	Low
	901	Maintenance	UF_4, MgF_2, U, U_3O_8	Low
	902	Maintenance Shop (RCRA)	UF_4, MgF_2, U, U_3O_8	Low
	903	Oil Storage Area	RCRA, TSCA	Low
	910	Reduction	UF_4, MgF_2, U,	High
	911	Jolters	MgF_2, U_3O_8	High
	912	F Machine and Capping	UF_4, MgF_2, U,	High
	913	Rockwell Furnaces - Molten Salt	MgF_2, U, U_3O_8, Residues	High
	914	Breakout Station	MgF2, U	High
	915	Turner-Hawes/Hoffman Vac System	UF_4, MgF_2, U_3O_8	High
	916	Cooling Tank	Contaminated Water	Low
	917	Spencer Portable Vacuum	UF_4, MgF_2, U, U_3O_8	High
	920	Casting	U_3O_8, Residues	High

Table D.1-15
Qualitative Assessment of Potential for Airborne Recycled Uranium Dusts (continued)

Plant	SRC	Operation	Material	Potential
9				
	921	NPR Furnace	U_3O_8, Residues	High
	922	Cin Milling Machine	U_3O_8	Medium
	923	NPR Sawing	U_3O_8, Residues	Medium
	924	NPR Primary Hoffman Dust Collector	U_3O_8, Residues	High
	925	NPR Bag Hoffman Vacuum Unit	U_3O_8, Residues	High
	926	NPR AAF Dust Collector	U_3O_8, Residues	High
	927	NPR AAF Dust Collector Separator	U_3O_8, Residues	High
	928	I&E Furnace	U_3O_8, Residues	High
	929	I&E Separating and Cooling	U_3O_8, Residues	High
	930	I&E Sawing	U_3O_8, Residues	Medium
	931	I&E Wheelabrator Dust Collector	U_3O_8, Residues	High
	932	I&E Primary Hoffman Dust Collector	U_3O_8, Residues	High
	933	G9-N1 1035 Dust Collector	U_3O_8, Residues	Medium
	934	I&E Hoffman Bag Vacuum Unit	U_3O_8, Residues	High
	935	Extrusion Sawing	U_3O_8, Scrap	Medium
	940	Machining	U_3O_8, Scrap	Medium
	941	Gisholt Lathe	U_3O_8, Scrap	Medium
	942	J&L Automatic Lathe	U_3O_8, Scrap	Medium
	945	L&S Duomatic Lathe	U_3O_8, Scrap	Medium
	949	J&L Turret Lathe	U_3O_8, Scrap	Medium
	951	LeBlond Rapid Borer	U_3O_8, Scrap	Medium
	953	Warner-Swasey Lathe	U_3O_8, Scrap	Medium
	954	Monarch Engine Lathe	U_3O_8, Scrap	Medium
	955	Briquetting	U_3O_8, Scrap	Medium
	956	Crusher and Metso Wash	U_3O_8, Contaminated Water	High
	957	Chip Pickling and Rinsing	U_3O_8, UNH, Scrap	Low
	958	Chip Centrifuging	U_3O_8, UNH, Scrap	Low
	959	Magnetic Separator and Briquette Press	U_3O_8, UNH, Scrap	Medium
	960	Pickling	U_3O_8, UNH	Low
	961	Remelt Pickling and Rinsing	U_3O_8, UNH	Low
	962	Core Degreasing and Pickling	UNH	Low*
	965	Sump Liquor Processing	U_3O_8, UNH, Residues	Low
	966	Collection Tanks	U_3O_8, UNH	Low
	967	Precipitators	U_3O_8, UNH	Low
	968	Filters	U_3O_8, UNH	Low
	970	Heat Treating	U_3O_8, Residues	Medium
	980	ZIRNLO - General	U_3O_8	Low
	981	Hacksaw	U_3O_8	Medium
	982	Degreaser	U_3O_8	Low
	983	Decoppering	U_3O_8	Low
	984	Dezircing	U_3O_8	Low
	985	Acid Filtration	U_3O_8, UNH	Low
	986	Neutralization	U_3O_8, UNH	Low
	987	Nitric Acid Pickle	U_3O_8, UNH	Low
	988	KOH Pickle	U_3O_8, UNH	Low

*Low in U, but high in degreasing solvent vapors.

Table D.1-15
Qualitative Assessment of Potential for Airborne Recycled Uranium Dusts (continued)

Plant	SRC	Operation	Material	Potential
Pilot	300	Pilot Plant General	UF_6, UF_4, U	Low
	301	Maintenance	UF_6, UF_4, U	Low
	302	Maintenance Shop (RCRA)	UF_6, UF_4, U	Low
	303	Oil Storage Area	RCRA, TSCA	Low
	310	Green Salt Production	UF_6, UF_4	High
	311	Reactor #1	UF_6, UF_4	High
	312	Reactor #2	UF_6, UF_4	High
	313	Dust Collectors	UF_6, UF_4	High
	314	Vacuum - Portable	UF_4, Residues	High
	315	Autoclave	UF_6	Low
	316	Cold Trap	UF_6	Low
	320	Metal Reduction	UF_4, MgF_2, U, Residues	High
	321	Sly Dust Collector	UF_4, MgF_2	High
	322	Hoffman Vacuum	UF_4, MgF_2, Residues	High
	323	Rockwell Furnaces	UF_4, MgF_2, U, Residues	High
	324	Breakout Station	U, MgF_2, Residues	High
	330	Derby Shot Blasting	U, MgF_2, Residues	High
	331	Pangborn Dust Collector	MgF_2, Residues	High
	332	Spencer Vacuum	MgF_2, Residues	High
	333	East Wheelabrator Dust Collector	MgF_2, Residues	High
	334	Duclone Cyclone	MgF_2, Residues	High
	335	Shot Production	U, U_3O_8	Medium
	336	Shot Tank	U, U_3O_8	Medium
	340	Remelt & Casting	U, U_3O_8, Residues	High
	341	Remelt Furnace	U, U_3O_8, Residues	High
	343	Crucible Burnout	U, U_3O_8, Residues	High
	345	Saws	U, U_3O_8, Residues	Medium
	346	West Wheelabrator Dust Collector	U_3O_8, Residues	High
	347	Hoffman Vacuum	U, U_3O_8, Residues	High
	350	Heat Treating	U, U_3O_8, Residues	Medium
	351	Salt Bath	U, U_3O_8, Residues	Medium
	352	Water Quench	U_3O_8, Contaminated Water	Medium
	353	Oil Quench	Contaminated Oil	Medium
	354	Vacated		
	355	Metal Dissolving	U, UNH	Low
	356	HNO3 Pickling or Decoppering	Acidic U Solutions	Low
	357	HF or HCl Dissolver	Acidic U Solutions	Low
	358	Filter	Acidic U Solutions, Residues	Low
	359	Neutralizer	Neutral U Solutions	Low
	360	Auxiliary Equipment	Thorium	Low
	361	Precipitator	Thorium	Low
	362	Filter	Thorium	Low
	363	Tray Dryer	Thorium	Low
	365	Oxidizing	U_3O_8, Residues	High
	368	Air Filter	U_3O_8, Residues	High
	369	S&W Glo-Bar Furnace	U, U_3O_8, Residues	High
	370	Milling	U, MgF_2, U_3O_8, Residues	High
	371	Jaw Crushers	U, MgF_2, U_3O_8, Residues	High

Table D.1-15
Qualitative Assessment of Potential for Airborne Recycled Uranium Dusts (continued)

Plant	SRC	Operation	Material	Potential
Pilot	372	Ball Mill	U, MgF_2, U_3O_8, Residues	High
	375	Solvent Extraction	UNH Solution, Organic	Medium
	376	6-Inch Columns	UNH Solution, Organic	Medium
	377	Boildown Tanks	UNH Solution	Low
	378	Product Tank	UNH Solution	Low
	379	2-Inch Columns	UNH Solution, Organic	Medium
	380	Pilot Plant Sump	Contaminated Water	Low
	381	Sump Catch Basin	Contaminated Water	Low
	382	Precipitator	Thorium	Low
	383	Uncontaminated Sump	Wastewater	Low

11.0 IDENTIFICATION OF FEMP PROCESSES WITH POTENTIAL TO CONCENTRATE CONSTITUENTS

The FEMP routinely received recycled uranium metal and compounds with trace quantities of transuranic constituent content as feed for government programs. Except for a limited number of specific material receipts, the uranium materials the FEMP received contained transuranics and other recycle constituents at levels below a concern for significant radiation exposure impacts. However, due to the possibility of concentration of these constituents in FEMP chemical processes, a review of these processes was performed during the development of this report to identify the probable locations for constituent concentration.

The review of FEMP processes was completed by process-knowledge experts from the operating period of the FEMP. The review utilized existing process flow charts and process history narratives to identify possible points of constituent concentration/separation. The review included consideration of other known concentration/separation results identified during the operating history of the FEMP. The following section identifies those processes/process steps that were identified as having potential for concentration/separation of constituents, while also providing a rationale for such consideration.

UF_6 to UF_4 Process

This process was performed at Plant 7 and the Pilot Plant at the FEMP at different times in the operating history of the site. Although not designed to remove Pu or other constituents from the uranium stream, the UF_6 feed process allows the more volatile fractions of the UF_6 stream to exit the feed cylinder, while less volatile fractions would be less likely to leave the cylinder. Since Pu fluorides are known to have an affinity for zero valence metals and to produce less stable fluoride gasses, the potential for Pu to be concentrated in the heel of the cylinder exists. The chemical process responsible for concentration of constituents in the heel fraction of the UF_6 cylinders is consistent with the evidence from the GDP Feed Plant concentration of less volatile Pu/Np fluorides in the Tower Ash. A study of UF_6 cylinder heel

constituent hold-up in DOE UF_6 cylinders. Exposure of FEMP workers to this more concentrated heel fraction of the UF_6 cyclinders would not not have occurred as a result of routine operations.

Hydrofluorination

This process reacted uranium di-oxide powder with HF to produce a UF_4 powder. The process is not believed to have permitted separation of constituents because regardless of chemical reaction, the powders were mechanically or pneumatically moved through the solid-gas reaction processes from start

to finish. The exception to this presumption is the situational data that suggests that the Tc99 constituent tended to volatilize in high temperature processes, such as hydrofluorination, and would tend to collect on dust collector residues and media.

Extraction

The extraction purification process for the FEMP was based on liquid/liquid countercurrent flows. The process was somewhat similar to the government processes that extracted plutonium from uranium at the Hanford and Savannah River DOE sites, however, the FEMP process was optimized to purify the uranium of many trace contaminants and was not optimized for Pu or Np separation from uranium. Several of the historical technical documents examined for this project predicted that ~80 percent of the Np and Pu would report to the aqueous raffinate from the extraction process. However, Plant Test Authorization (PTA) 302 (1977) determined that 87.2 percent of the initially fed Pu and 41.6 percent of the initially fed Np appeared in the product UO_3 stream of the process. These results were based on an overall material balance performed during the PTA.

Nonetheless, a fraction of the Pu and Np fed to the extraction process would appear in the byproduct stream known as raffinate. The raffinate, low in uranium content by design, would be expected to present a high Pu/Np value when reported on a uranium assay basis (Pu/Np relative to U content). Extraction raffinate was neutralized and subsequently pumped to FEMP waste pits as a slurry.

Reduction

The reduction process heated UF_4 powder mixed with magnesium metal turnings in a lined and sealed vessel to initiate a reaction to form uranium metal. The uranium metal initially formed in a molten phase and quickly solidified in the base of the vessel. The level of solubility of Pu and Np, and probably some uranium decay daughter products, in the molten uranium would determine the potential for separation of these constituents from the uranium. A study published in 1975 (NLCO-1130) reported that 46 percent of the initially fed Pu and 63 percent of the initially fed Np reported to the MgF_2.

Because of evidence from the casting operation that a significant portion of the higher radioactivity uranium daughter products (Th & Pa) tended to become excluded from the uranium matrix, the potential for a similar mechanism separating the transuranics at the reduction operation may have been occurring. Based on these results, the MgF_2 produced would be expected to have relatively higher levels of Pu and Np than the materials fed to the process.

The operation to remove the uranium derby and MgF_2 from the reduction vessels could have been an exposure point, if concentration occurred in the MgF_2. The MgF_2 milling operations and the operation for forming a MgF_2 reduction vessel liner could have been as well. Downstream operations to recover uranium from enriched MgF_2 could be affected.

Vacuum Casting

The casting operations utilized several different physical forms of uranium metal as feed. The ingots and billets produced in the casting operations often would exhibit higher surface radioactivity than materials fed to the process, indicating either a propensity for certain radioactive elements to be insoluble in molten uranium or potentially indicating an affinity between mold coating materials and certain radioactive species. This evidence provides a basis for postulating a Pu and Np separation from uranium at this process step. A study published in 1975 (NLCO-1130) reported that 5 percent of the initially fed Pu and 64 percent of the initially fed Np reported to the crucible residuals or graphite (or were otherwise not in the final metal product). Other results in the report claim a 40 percent share of Pu reporting to the crucible residuals. Ingot/Billet handling, mold handling, crucible handling, and furnace maintenance operations would be affected.

Metal Pickling

Pickling the uranium metal products in nitric acid removed surface layers of oxides and generally reduced surface radioactivity dramatically. Concentration of recycled uranium constituents relative to uranium content in pickling liquors is postulated. However, these liquids would have been processed either in sump operations to form sludges or sump cakes, or would have been returned to the Refinery for recovery of uranium contents.

Machining Operations

A wide variety of machining operations were employed to shape uranium metal to product specifications. After most casting steps, the removal of a "top crop" was performed to separate porous and contaminated metal. It is likely that top crops contained greater quantities of recycled uranium constituents than the higher quality fraction of the metal product or the original casting feed materials. Top crops would either be refed to the casting operation or dissolved in acid (at a metal dissolver operation) for feed to the Refinery. Exposure points would have been minimal, since the material was either handled as a consolidated solid or as a contained liquid.

Recovery Operations

A number of operations utilized to recover scrap or residue uranium content were employed by the FEMP. A variety of milling capabilities supported oxidation/furnacing processes and a process for acid leaching of MgF_2. The powdered form of materials handled in many of these processes would increase the opportunity for worker contact with recycled uranium constituents.

Non-Routine Events

Maintenance Operations

Because of the wide variety of maintenance operations that could be required to keep a large production complex, such as the FEMP, in operation, there is a potential that maintenance work would result in access to portions of the production processes not typically accessed during routine operations. These non-routine accesses would potentially increase the worker contact with recycled uranium constituents.

Unintentional Releases

Uranium fires, airborne emissions from scrubbers and dust collectors, and other accidental and otherwise unintentional releases of uranium and its constituents would have presented additional opportunities for contact with uranium recycle constituents.

References

NLO Health & Safety Division, "NLCO-1130 Special, Environmental Assessment of the Processing of Reactor Recycle Materials Containing Transuranium Elements," November 11, 1975.

J. H. Cavendish, Letter to C. E. Polson, "Completion Report, PTA-302; Refinery Processing of Paducah Scrap Materials," January 26, 1977.